[Tentative Translation]

Summary of the ILC Advisory Panel's Discussions to Date after Revision

July 4, 2018

International Linear Collider (ILC) Advisory Panel

Contents

1. Discussion Background and Target 1

2. Overview of Discussions
(1) Scientific Merit 4
(2) Validation of Cost Estimation and Technical Feasibility 5
(3) Validation of Human Resource Development 5
(4) Validation of Organization and Management 6
(5) International Cooperation 7
(6) Examples of Large Accelerator Facilities 9

3. Summary of the Discussion to Date on the Revised ILC Project 11

Details of Discussions
(1) Scientific Merit 15
(2) Validation of Cost Estimation and Technical Feasibility 25
(3) Validation of Human Resource Development 37
(4) Validation of Organization and Management 47

Supporting Documents 73
・International Linear Collider (ILC) Advisory Panel membership
・Elementary Particle Physics and Nuclear Physics Working Group membership
・Technical Design Report(TDR) Validation Working Group membership
・Human Resource Securing and Developing Working Group membership
・Organization and Management Working Group membership
・ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory
・Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community
・Reply from the Linear Collider Board to the MEXT Particle and Nuclear Physics Working Group
・Overview of E-XFEL, FAIR
・International Organizations of ILC Researchers
・Challenges and activities to understand natural laws in a unified framework
・Focal Points for the Advisory Panel on the Report Entitled "Re-calculation Results of Economic Ripple Effects on International Linear Collider (ILC) Project"

1. Discussion Background and Target

(1) Discussion Background

- The International Linear Collider (ILC) project, which was planned originally to deliver electron-positron collisions at 500GeV for experiments by using a 30km long linear accelerator, has been expected to elucidate how the universe was created and to advance elementary particle physics to enter into a new stage, by investigating in detail the Higgs boson, a particle to generate mass, and by discovering new particles beyond the Standard Model.
- The international researchers' community of elementary particle physics has initiated a design effort of the ILC as a global project and has completed the Technical Design Report (hereinafter TDR) in June 2013. The international ILC community subsequently proposed the ILC to be constructed in Japan and proponents in Japan have promoted a campaign to invite the ILC anticipating developing an international science city.
- Under these circumstances, MEXT decided to start examining the ILC project.

(2) Discussion at MEXT in Response to the Report (September 2013) by Science Council of Japan

- In May 2013, MEXT made a request to Science Council of Japan (hereinafter SCJ) to deliberate scientific merit and related issues of the ILC project. As a response to the above request, SCJ published a document, "Report on the International Linear Collider Project" (hereinafter SCJ Report) in September 2013, addressing that "*the ILC is endowed with a scientific value in particle physics, however, given the considerable investment it will require, SCJ expresses the desire for more compelling and articulate argument to justify the ILC project and its concurrent running with the upgraded LHC." SCJ concluded that "it is too early to grant the full-scale implementation at the moment" and recommended that "the government of Japan should (1) secure the budget required for the investigation of various issues to determine the possibility of hosting the ILC, and (2) conduct intensive studies and discussions among stakeholders, including authorities from outside high-energy physics as well as the government bodies involved, for the next two to three years.*"
- In response to the SCJ Report, MEXT established the International Linear Collider Advisory Panel (hereinafter Advisory Panel) in May 2014 to discuss various ILC related issues.
- The Advisory Panel decided at its first meeting to create two working groups, the Elementary Particle Physics and Nuclear Physics Working Group (hereinafter Physics WG) and the TDR-Validation Working Group (hereinafter TDR WG), to discuss science merit of the ILC given a considerable investment and issues addressed in the TDR such as cost

estimation and technical feasibility respectively. By March 2015, the Physics WG held eight meetings and the TDR WG held six meetings and published respective reports.

- In parallel, MEXT has conducted subcontracted projects, "Survey of spin-off effects of the ILC project from technical and economic aspects and research trends in elementary particle physics and nuclear physics including necessary technologies in the world" (hereinafter Survey.)
- Two WG reports, together with a report of the Survey, have been presented at the third Advisory Panel meeting. At its fourth meeting, held on 25 June 2015, the Advisory Panel completed a report, "Summary of the International Linear Collider (ILC) Advisory Panel's Discussions to Date" (hereinafter Discussions to Date in 2015).

(3) Discussions after summarizing Discussions to Date in 2015

- At its fourth meeting, the Advisory Panel, in consideration of the future issues pointed out in the Discussions to Date in 2015 as well as the SCJ Report, decided to create Human Resources Securing and Developing Working Group (hereinafter Human Resources WG), which held six meetings to discuss the issues related to human resources, and at its fifth meeting published a report on 7 July 2016, "Report on Measures to Secure and Develop Human Resources for the International Linear Collider."
- At its sixth meeting held in February 2017, the Advisory Panel decided to create Organization and Management Working Group, which held six meetings to discuss the following issues: organization and management of an international research institution, the living environment and social infrastructure of the surrounding area, and the domestic organizational structure in case that the international organization is founded in Japan. At its sixth meeting, the Advisory Panel published a report on 28 July 2017, "ILC Advisory Panel Report on ILC Organization and Management."
- Since then, the Linear Collider Collaboration (LCC), an international organization of researchers involved in the ILC project, submitted a revised plan to the Linear Collider Board (LCB), an international committee for the promotion of the ILC. The LCB has approved the revised plan[1] and submitted it to the International Committee for Future Accelerators (ICFA). The ICFA endorsed the revision[2] and made a public announcement in November 2017. The revised plan proposes an ILC operated at a collision energy of 250 GeV (hereinafter 250 GeV ILC), instead of the original 500 GeV ILC, based on the results

[1] "Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community" (Linear Collider Board, 8 November 2017, Rev 1)
[2] "ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory"(Ottawa, November 2017)

obtained in 13 TeV LHC experiments using data collected by the end of 2017, together with due consideration of cost reduction.

- In response to the revised plan, the Advisory Panel, at its eighth meeting held in December 2017, decided to reconvene the Physics WG to revisit the scientific merit and the TDR WG to re-examine the cost estimation and technical feasibility. Each WG held five meetings to scrutinize the revised plan incorporating the latest available knowledge and the respective reports were presented at the ninth Advisory Panel meeting held in May 2018.
- In addition, MEXT subcontracted researches/surveys as listed below in support of the Advisory Panel and the WGs:
  - Survey on the technical feasibility and technological issues in accelerator construction for the ILC project (February, 2016)
  - Report of the analysis of international cooperation on large international projects (March, 2017)
  - Survey on regulations and risks relevant to the ILC project (February, 2018)
  - Research on cost reduction of the international large-scale accelerator-based facility (February, 2018)

(4) Rationale for this Document

- In response to the proposal of the ILC revised plan based on the results obtained in the LHC experiments, two WGs reconvened; the Physics WG was to revisit scientific merit and the TDR WG was to re-examine cost estimation and technical feasibility. On receiving the reports from these two WGs, the Advisory Panel issues this report, "Summary of the ILC Advisory Panel's Discussions to Date after Revision," (hereinafter Discussions to Data after Revision) to clarify the entire picture of the ILC project as much as possible.

2. Overview of Discussions

The Advisory Panel summarizes in this report inquest into scientific merit, cost estimation and technical feasibility, securing and developing human resources, organization and management, and international cooperation conducted by the Advisory Panel and WGs in order to update the entire picture of the ILC taking into account the study result described in the Discussions to Date in 2015.

(1) Scientific Merit

- The results of the LHC experiments as of the end of 2017 have indicated the absence of an evident hint of new particles beyond the Standard Model, such as strongly-interacting SUSY particles, or new phenomena such as dark matter or extra dimensions, although a variety of other results have been obtained since the discovery of Higgs boson. The results have also indicated that the chance for new particles and/or new phenomena to be observed by the end of 2018 during the 13 TeV LHC Phase II operation is small.

- Based on the above observations and taking into account the importance of precision measurements of the Higgs boson, the international researchers' organization proposed a revised ILC plan where the machine operates as a Higgs factory by changing the collision energy from 500 GeV to 250 GeV. In response to this revised plan, the Advisory Panel has reviewed the scientific merit of the 250 GeV ILC.

- The strongest advantage of experiments at the 250 GeV ILC is their capability to precisely measure the couplings of the Higgs boson. If any coupling(s) is measured to be different from the Standard Model prediction, a particle-by-particle pattern of the deviation will elucidate the nature of new physics, suggesting a future direction of elementary particle physics. Mysteries in the Standard-Model such as the nature of dark matter and compositeness of the Higgs boson may also be clarified with this measurement.

- Advantage of the 250 GeV ILC for precision Higgs measurements has been confirmed by the following two facts: the production cross section of the Higgs boson is at a maximum at around 250 GeV, and the non-observation of new particles at 13 TeV LHC ensures that the effective field theory is applicable to extract precisely the Higgs couplings to the other elementary particles.

- The change in the collision energy from 500 GeV to 250 GeV, on the other hand, precludes the precision measurements of the top quark, which require a collision energy of at least 350 GeV.

- Non-observation of new particles at LHC by the end of 2017 indicates that the discovery chance for new particle(s) such as a non-strongly interacting super-symmetric particle would be even smaller at the 250 GeV ILC although they have been thought to be discovered at ILC in spite of difficulty of discovery at LHC.

- Indirect searches* for dark matter particles or particles related to extra dimensions by various methods, such as the measurement of large missing energy, are still effective even at the 250 GeV ILC.

  * Measurements of invisible decays of the Higgs boson, single-photon events, and radiative corrections to the pair-production of Standard Model particles.

(2) Validation of Cost Estimation and Technical Feasibility

- The estimated construction cost* of the revised 250 GeV ILC presented at the Advisory Panel is 735.5~803.3 billion-yen (635.0~702.8 billion-yen for the accelerator and 100.5 billion-yen for the detectors.) Additional expenses may arise from an inaccuracy (ca. 25%) in the cost estimation.

  * The cost of the original 500 GeV ILC was estimated to be 1091.2 billion-yen (990.7 billion-yen for the accelerator and 100.5 billion-yen for the detectors.)

- The annual operation cost has been estimated to be 36.6~39.2 billion-yen*. A supplementary cost in a preparatory phase has been estimated to be 23.3 billion-yen. An additional cost, such as a site-specific expenditure, may add up.

  * The annual operation cost of the original 500 GeV ILC was 49.1 billion-yen.

- The contingency, a reserve for unforeseeable expenditure, has been estimated to be about 10 % of the project cost (construction of the accelerator and the detectors, and operation.) The cost of decommissioning, which has been newly estimated to be equivalent to the cost of two years of operation, has been clearly specified.

- The above cost estimation, provided by the researchers' community, incorporated some counter-measures against cost risks. A tangible progress in the cost reduction has been demonstrated by the change of the collision energy as well as new development of superconducting cavities compared to the estimated cost described in the Discussions to Date in 2015. The Advisory Panel points out that additional cost in association with the "risk factors and technical issues," such as technical risk, schedule risk arising from the extension of construction period, and market risk, should be carefully considered.

- As pointed out in the Discussions to Date in 2015, there still remain issues on several subsystems, such as beam dump, positron source, electron source, beam control, and the injection/extraction of the damping ring. The technologies of these under-performing subsystems should be completed during the preparatory phase, especially for the beam dump. Long term stability and maintenance scenario of the beam window, and resistance to the earthquake should be developed and completed in the preparation period.

- The countermeasures should be developed against conceivable risks and relevant legal regulations: civil engineering, radiation safety, earthquake, mountain spring water, and environmental impact.

(3) Validation of Human Resource Development

- The human resources required annually for the ILC accelerator project during the nine-year period of construction has been estimated to be about 830 for construction and about 380 for installation*. These are averages of seven years from the third to ninth year.

* For the 500 GeV ILC, 1,100 for construction and 480 for installation.

- A significant amount of human resources must be engaged domestically and internationally when a large-scale international cooperation project like the ILC is undertaken. It is evident that currently available human resources are not sufficient and introduction of a new employment system is indispensable. The CERN's employment system, Project Associates*, which has been introduced for the construction of the LHC, should be referred to.

  * An employee of an outside institution participating in a project at CERN returns to his/her original institution after the engagement at CERN completes. CERN has no responsibility for his/her employment. A work experience at CERN, a prestigious institution, would help enhance his/her job opportunity at an international organization or project.

- It is necessary to train and secure experts capable of managing large-scale projects as well as experts capable to grasp the entire project including large-scale accelerator.

- It is important to involve younger generation in the management of the entire system taking every opportunity of renovation and major upgrade of existing facilities, both domestic and international, so that they can play leading roles in the future projects.

- International sharing of human resources is assumed to be coordinated carefully with partner institutions abroad for salary and other working conditions. It is also important to plan and develop comprehensive infrastructure, including housing and life support for family members, with a support from local community.

(4) Validation of Organization and Management

- Researchers' community assumes that a multi-national pre-laboratory will be established based on an agreement among research institutions with the consent of respective governments for the first period of four years to finalize the engineering design and to coordinate task assignment among participating countries. Then the pre-laboratory will evolve into a treaty-based international organization, the ILC Laboratory, and after a nine-year period of construction the international collaborations will start experiments.

- The headquarters of the pre-laboratory is assumed to be located at KEK. It should be noted that the timing and range of resources to be relocated from KEK to the pre-laboratory should be discussed with domestic and international partners. The relocation should not interfere with other research projects to be completed at KEK.

- It is reasonable to establish and operate the ILC Laboratory as an inter-governmental treaty-based organization because its facilities and equipment require multi-national cooperation and long-term governmental commitments of partner countries. It is also crucial to invite a capable researcher with an international recognition as the head of the ILC Laboratory to manage the entire project.

- The fabrication of equipment is assumed to be shared among partners as their in-kind contributions in conformity to respective local workflow conventions. In order to avoid delays and cost overrun, it is essential to prescribe clearly the rules and define the extent of authority for a change of specification. It is also important to secure an appropriate amount of budget for unforeseeable situations.
- Considering a recent research environment, in which researchers are able to carry out data analysis at their home institutions thanks to high-speed internet connections, the ILC-related population around the site is expected to decline after the completion of construction. An increase of CERN-related population around the CERN site should be considered as a side effect of its location in the vicinity of a cosmopolitan city, Geneva.
- Support from local governments is indispensable in providing public facilities and services to satisfy a variety of requirements for living environment and social infrastructure as assumed for the ILC Laboratory.
- Establishing a national consortium for the detector development and data analysis, as a framework for Japanese universities to participate in an international collaboration, is effective in making their strong presence and promoting their internationalization.
- Under the financial constraint, it is difficult to maintain the present funding level of KEK as it is in addition to the establishment and operation of the ILC Laboratory. Therefore, the high-energy physics community should establish a consensus on their future plan by carefully selecting projects and focusing available resources.
- Future prospects of the industrial application of superconducting cavity technology is unclear at present. Therefore, its spin-offs and technology transfer should be promoted by means of close collaborations with industry. The management of ILC is deemed difficult beyond the capacity of a team composed solely of researchers. A collaboration between academia and industry should be established to manage the project.

(5) International Cooperation

- The ILC is an international project requiring an enormous investment. It is essential to conduct the project in cooperation with international partners and the cost should be shared among the partners. Accordingly, the willingness of every potential partner to make a reasonable contribution should be confirmed.
- According to the Discussions to Date in 2015, "*the European and American particle physics community expects Japan to proceed with the ILC project in line with their strategies.*

However, current plans and budget of their countries do not explicitly define the ILC project. It is necessary to proceed based on worldwide attitudes to the ILC project."

- When the international researchers' organization announced the revised plan of the ILC project in November 2017, they recommended construction of the 250 GeV ILC in Japan and anticipated appropriate cost sharing exemplified in European XFEL and FAIR; these are international projects in which a major contribution*, including the civil engineering and other infrastructure, is provided by the host country. (See page 81 of the original text.)

  * The host contributes 58 % for European XFEL and 69 % for FAIR. These projects are described in detail in "(6) Examples of large accelerator facilities."

- The Advisory Panel inquired the intention of exemplifying these two projects, the LCB's response was as follows; "*The two accelerator based research facilities, European X-ray Free Electron Laser (European XFEL) and Facility for Anti-proton and Ion Research (FAIR), to be relevant for the current ILC discussion in the following two aspects: For both cases, the host country, Germany, (1) carried a considerable fraction of the cost, and (2) declared first their intention to host the facility with a significant contribution and then took initiative to form an international collaboration and to play a leading role in the project realisation. According to the LCB opinion, the host country needs to take a leadership in forming an international collaboration in order to achieve timely construction of the ILC project at the present moment. Indicating the intention of making an appropriate contribution as a host country is highly desirable to start such process.*" (Original text is in page 82.)

- On the premise that a fractional contribution in the revised plan is higher for the host country and lower for others, the international researchers' organization has expressed their desire that Japan declares its intention to host the ILC project and to take initiative to form an international collaboration. The expected host contribution, however, is higher than other international big-science projects* in which Japan has participated. Under the tough financial condition in Japan, the international cost sharing should be realistic and sustainable.

  * Examples of international cost sharing presented at the Organization and Management WG:

  ITER (International Thermonuclear Experimental Reactor): 45.46% for Europe, the host region, 9.09% ea. for other participating regions.

  CERN: Share of expenditure is proportional to the average of Net National Income (NNI) for the latest three years.

  ALMA (Atacama Large Millimeter/submillimeter Array): Starting from an equal sharing among three regions, Japan, the United States and Europe, the final contribution after reconciliation was set to be 25 % for Japan and 37.5 % ea. for the U.S. and Europe.

- The ILC has been promoted as an international academic project with the support of relevant international researchers' organizations. Therefore, it is important to attain a proper balance between the host and the others paying attention to secure sufficient contributions from participating countries while keeping decentralized authority and responsibility.

- In May 2016, MEXT and U.S. Department of Energy (DOE) opened a dialogue on the ILC project and, based on a mutual understanding on the importance of cost reduction, launched a collaboration between KEK and Fermi National Accelerator Laboratory (FNAL) for this purpose.

- MEXT exchanged opinions with Ministry of Higher Education, Research and Innovation (MESRI), France, in March 2018 and German Federal Ministry of Education and Research, (BMBF) in May 2018. Both partners pointed out the same comments as described below:

  - A reference to the ILC project in the European Strategy for Particle Physics Update, which is slated to be published in May 2020, may exert a certain influence on the government-level decision, however, considering the nature of the strategy document being published from a scientific viewpoint, it will not necessarily guarantee any governmental decision to fund the ILC project.
  - The funding process for a large project in France and Germany is similar to that of Japan. The decision is based on an evaluation of entire science community and subsequent priority-setting by the administration. The contribution of governments of France and Germany to the ILC project should be deliberated along the same line.

- The international cost sharing will be decided by the inter-governmental negotiations between partner countries. At this moment, however, the ILC is not ranked in any government-level planning nor scheduled funding in any country. Therefore, it is important first to have realistic prospects for the commitment and financial contributions of potential partner countries. An inter-governmental agreement will be reached only after the project is approved by a science council or its equivalent in each country and progress towards securing the budget is inevitable in each country.

- It should be noted that the ILC project will lose international momentum if decisions on the ILC project implementation are not made in a timely manner.

(6) Examples of Large Accelerator Facilities

- The most expensive accelerator built in Japan so far is J-PARC, which costed about 150 billion-yen*. Other examples include SPring-8 (ca. 110 billion-yen*) and KEKB (ca 37.8 billion-yen**). Compared with these precedents, the ILC is much more expensive. Therefore, an accurate cost estimate is essential and scientific merit should be verified to be commensurate with the enormous investment.

* J-PARC and SPring-8: Beam lines constructed in the construction period are included. Labor cost is not included.

** KEKB: An existing tunnel is utilized. Labor cost is not included.

- LHC is the largest accelerator in the world at this moment. While utilizing an existing tunnel, an additional construction cost for LHC is about 500 billion-yen apart from the labor cost.
- As described in the previous section, (5) International cooperation, LCB denoted European XFEL and FAIR as examples of recent international projects of the same kind. The outline of these two projects are illustrated below.

[1] European X-ray Free Electron Laser (E-XFEL)

- The construction cost, 1.22 billion-euro (ca. 167 billion-yen), is shared among Germany (58 %), Russia (27 %), and ten other countries (1~3 % ea.).
- In 2003, in response to a proposal submitted by DESY, German government expressed its willingness for the construction of XFEL and its readiness for a 50% contribution. Following these actions, the government-level negotiations started.
- At first, contributions from European countries for the construction were limited to 1~3 % each. However, since Russia expressed its participation in 2009 with a contribution of 250 million-euro (34.2 billion-yen), the treaty for an international project has been concluded and the construction started.
- Since then, the construction continued as planned despite cost overrun for the accelerator. In consequence of a delay of one year, the construction cost has increased by about 13 % compared with the estimate at the time of signing the treaty.
- A recollection of a researcher involved in the project;

  - *An administrative complexity, arising from the cost sharing, could be mitigated if Germany could undertake full responsibility for civil engineering.*

[2] Facility for Anti-proton and Ion Research (FAIR)

- The construction cost, 1.262 billion-euro (ca. 173 billion-yen), is shared among Germany (69 %), Russia (17 %) and seven other countries (0.5~3.5 % ea.).
- In 2003, the German government approved the FAIR project on the condition that a quarter of the construction cost should be collected from abroad. Since then, the government-level negotiations started.

- At first, contributions from European countries for the construction were limited to 0.5~3.5 % each. However, since Russia expressed its participation in 2010 with a contribution of 180 million-euro (24.6 billion-yen), the treaty for an international project has been concluded and the construction started.
- Since then, the German government suspended the construction because of cost increase arising from countermeasures against the soft ground of the site and the radiation safety standards considering the East Japan Great Earthquake Disaster. After revising the project based on an external review, the construction re-started in 2017 and is slated to be completed in 2025. In consequence of a delay of eight years, the construction cost has increased by about 23 % compared with the estimate at the time of signing the treaty.
- A recollection of a researcher involved in the external review;
    - *The project management did not function well and the communication between groups and layers was poor.*
    - *The major cause of the increase of the cost and the delay in the schedule lies in the disordered civil construction, which was fully undertaken by Germany. The technical management of the accelerator and detectors are in better shape.*
    - *The scientific merit of the project has been appreciably diminished due to an extended delay.*
- Superconducting Super Collider (SSC) was planned in the U.S. in the same period as LHC. The project halted halfway at a later time. A recollection of a researcher involved in the project; Lessons could be learned from the following conceivable factors of the cancellation;
    - The U.S. fiscal policy turned to austerity budget.
    - The cost increase from 4.5 to 11 billion-dollar due to changes in the design.
    - The exaggerated spillover effect evoked a bad feeling.
    - The selected site on a green field has brought up various problems.

3. Summary of the Discussion to Date on the Revised ILC Project

The ultimate goal of elementary particle physics is to understand natural laws of elementary particles and universe in a unified framework. Many important experimental programs are in progress with a variety of approaches to study, for example, the unification of forces, the super-symmetry, and other physics beyond the Standard Model. (See page 86 "Challenges and activities to understand natural laws in a unified framework.")

The ILC project is expected to make a significant contribution in the search for physics beyond the Standard Model and in exploring new physics by investigating in detail the properties of the Higgs boson and by discovering new particles. In response to the SCJ Report (September 2013), MEXT launched an Advisory Panel to scrutinize the ILC project (original 500 GeV ILC) and made the following recommendations.

(Recommendations in Discussions to Date in 2015)

Recommendation 1: The ILC project requires so huge investment that a single country cannot cover, thus it is indispensable to share the cost internationally. From the viewpoint that the huge investments in new science projects must be weighed based upon the scientific merit of the project, a clear vision on the discovery potential of new particles as well as that of precision measurements of the Higgs boson and the top quark has to be shown to clarify the strategy to go beyond the Standard Model of the particle physics.

Recommendation 2: Since the machine performance and scientific achievements of the ILC project are to be designed based on the results of LHC experiments by the end of 2017, it is necessary to closely monitor, analyze, and examine the development of LHC experiments. Furthermore, it is necessary to clarify how to solve technical issues and how to mitigate cost risk associated with the project.

Recommendation 3: While presenting the total project plan, including not only the plan for the accelerator and related facilities but also the plan for other infrastructure as well as efforts pointed out in Recommendations 1 & 2, it is important to have general understanding of the project by the public and science communities.

The international researchers' community proposed the revised plan of the ILC project based on the results obtained by the LHC experiments. In response to the revision, the Advisory Panel, taking into account the above Recommendations, has carried out surveys and discussions on the revised plant (250 GeV ILC) by means of hearings from and analyses by researchers' community. The Advisory Panel summarizes the discussion as follows to clarify the entire picture of the ILC project as much as possible.

Scientific Merit

- According to the results obtained by the LHC experiments by the end of 2017, there is no indication of new particles nor new phenomena such as dark matter or extra dimensions. The chance for new particles and new phenomena to be observed by the end of 2018 during the LHC Phase II operation has turned out to be small.
- The strongest advantage of the 250 GeV ILC lies in its capability of the precise measurements of the Higgs boson thanks to the maximum production cross section at 250 GeV. If the precisely measured Higgs couplings are different from the Standard Model prediction, the particle-by-particle pattern of deviations will indicate a solution to the

mysteries of the Standard Model, for example, whether the Higgs boson is elementary or composite, and may suggest a future direction of elementary particle physics.

- Based on the results obtained by the LHC experiments, the discovery potential of new particles is now limited to particles, which had been deemed difficult to detect at LHC while possible at the ILC. The revised ILC, operating as a Higgs factory with a reduced collision energy of 250 GeV, precludes the precision measurements of the top quark, which requires a collision energy of at least 350 GeV.
- The 250 GeV ILC is still a tool to search for new particles such as dark matter that could be detected indirectly through the observation of large missing energies.

Validation of Cost Estimation and Technical Feasibility

- While the revision of the ILC project has brought a significant cost reduction for the accelerator and civil engineering including the tunnel, it still requires an enormous investment, beyond the capacity of a single country, and accordingly the international cost sharing is indispensable.
- While some R&Ds aiming at the cost reduction turned out to be effective, other risk factors and technical issues that may bring about an additional cost should be carefully considered.
- There still remain issues on several subsystems such as beam dump, positron source, electron source, beam control, and the injection/extraction of the damping ring. The technologies of these under-performing subsystems should be completed during the preparatory phase.

International Cooperation

- On the premise that a fractional contribution in the revised plan is higher for the host country and lower for others, the international researchers' organization has expressed their desire that Japan declares its intention to host the ILC project and to take initiative to form an international collaboration. The expected host contribution, however, is higher than other international big-science projects in which Japan has participated. Under the tough financial condition in Japan, the international cost sharing should be realistic and sustainable.
- The ILC has been promoted as an international academic project with the support of relevant international researchers' organizations. Therefore, it is important to attain a proper balance between the host and the others paying attention to secure sufficient

contributions from participating countries while keeping decentralized authority and responsibility.

- The international cost sharing will be decided by the inter-governmental negotiations between partner countries. At this moment, however, the ILC is not ranked in any government-level planning nor scheduled funding in any country. Therefore, it is important at first to have realistic prospects for the commitment and financial contributions of potential partner countries. An inter-governmental agreement will be reached only after the project is approved by a science council or its equivalent in each country and progress towards securing the budget is inevitable in each country.
- Remedy for Human Resource Development and Organization and Management have been proposed assuming international coordination. It should be noted, however, that a lack of fair prospect may pose an obstacle to the project.

Dissemination to General Public and Science Community

- In response to the SCJ Report (September 2013) issued by SCJ, the Advisory Panel has conducted surveys and discussions for both the original ILC (500 GeV ILC) and the revised project (250 GeV ILC) to clarify the entire picture of the ILC as much as possible from various viewpoints: scientific merit, cost estimation and technical feasibility, human resource development, organization and management, and international cooperation.
- It is vital that the entire picture of the revised ILC should be disseminated to and shared among the general public, science community in particular, to gain the understanding and support for the scientific outcome and other ripple effects expected from the ILC project before making a decision of the ILC, a project requiring an enormous investment, considering an impact on academic circles as well as the mid- and long-term financial circumstances in Japan.
- Referring to a message in the SCJ Report, stating that "upon completion of the above investigation, SCJ is prepared to contribute to the government's decision by presenting scientific and academic perspectives," and in light of the significance of a report issued by SCJ, an institution representing the entire science community in Japan, the Advisory Panel anticipates that SCJ revisit the ILC project by making the most of this report.

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Details of Discussions

(1) Scientific Merit

Scientific Merit

The Elementary Particle Physics and Nuclear Physics WG (hereinafter "the Physics WG") has scrutinized the scientific merit of the ILC and discussed whether it justifies the large investment. After holding eight meetings since June 2014, the Physics WG completed a report (hereinafter the "Previous Report") in March 2015. In June 2015, having received the Previous Report, the ILC Advisory Panel (hereinafter the "Advisory Panel") published a document (hereinafter "Discussions to Date") summarizing the discussion thus far on a proposal for a 500 GeV[1] ILC.

Since then, the Linear Collider Collaboration (LCC), an international organization of researchers involved in the ILC, submitted a revised plan[2] to the Linear Collider Board (LCB), an international committee for the promotion of the ILC. The LCB has approved the plan and submitted it to the International Committee for Future Accelerators (ICFA)[3]. The ICFA endorsed the revision and made a public announcement[4] in November 2017. The revised plan proposes a 250 GeV ILC, based on results obtained by the experiments at 13 TeV LHC by the end of 2017, together with due consideration of cost reduction. In response to the revised plan, the Advisory Panel met in December 2017, and reconvened the Physics WG to re-examine the scientific merit and relevant issues from experts' viewpoint. The Physics WG held five meetings since January 2018 to revisit the Previous Report incorporating up-to-date scientific results and produced this report.

1. Results obtained in the experiments at CERN

- It was pointed out in the Previous Report and Discussions to Date that the decision of ILC specifications and the evaluation of expected achievements should be made after the results obtained in the Phase II operation of the LHC at 13 TeV.
- The LHC Phase II operation at 13 TeV extends to 2018, although the original schedule was from 2015 to 2017. The physics WG studied the LHC results until the end of 2017, and noted the significant progress of the LHC experiments since the Higgs boson discovery, and the absence of any clear indication of new particles beyond the Standard Model, such as strongly-interacting SUSY particles, or new phenomena such as dark matter or extra dimensions.

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1 Electronvolt (eV): A unit of energy. 1 eV is the energy gain of an electron accelerated by 1 volt gap.

2 「Physics Case for the 250 GeV Stage of the International Linear Collider」(LCC Physics Working Group / October, 2017) , 「The International Linear Collider Machine Staging Report 2017」(Linear Collider Collaboration / October, 2017)

3 「Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community」(Linear Collider Board, 8 November 2017, Rev 1)

4 「ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory」(Ottawa, November 2017)

- The results obtained by the LHC experiments so far indicate that the chance for new particles and new phenomena to be observed by the end of 2018 during the LHC Phase II operation is small and that of the three scenarios defined in the Previous Report, scenario (3) "no new particles or new phenomena are observed at the 13 TeV LHC", not (1) or (2), now applies. In response to this result, the international community of elementary particle physicists has reconsidered the collision energy of the ILC and decided to change it from 500 GeV to 250 GeV, taking into account the significance of precision measurements of the Higgs boson. Therefore, the content of the Previous Report should be revised accordingly.

Excerpt from the Previous Report 6. (1)-(3)

6. Possible scenarios following the results obtained at the 13 TeV LHC

A strategic plan of the ILC project based on possible scenarios following the results obtained at the 13 TeV LHC is as follows;

(1) In case that new particles, such as strongly-interacting supersymmetric particles, are discovered at the 13 TeV LHC.

Plan: The ILC will clarify the physics principle behind the new particles by means of precision measurements of the Higgs boson and top quark. If it is indicated that a strongly-interacting particle is relatively light[5], or that it may decay into other new particles with mass below 250 GeV, ILC will discover these new particles and study them in detail. If not, a future energy upgrade will be necessary.

Outcome: A big discovery and breakthrough are expected leading to a confirmation of supersymmetry or composite Higgs models. If a new particle is discovered at the ILC, a further breakthrough in research is anticipated.

(2) In case that new phenomena not specified in (1), such as dark matter and extra dimensions, are observed or discovered at the LHC experiments.

Plan: The ILC will study physics beyond the standard model by investigating the new phenomena discovered at the LHC and by making precision measurements of the Higgs boson and top quark.

Outcome: A big discovery and breakthrough are expected with the first observation of dark matter or the hint of extra dimensions.

[5] According to a typical supersymmetric theory, the mass of the lightest particle that might be discovered at the ILC is expected to be less than one seventh of that of the strongly-interacting supersymmetric particle. However, it should be noted that the theoretical uncertainty is large.

(3) In case that no new particles or new phenomena are observed at the 13 TeV LHC.

Plan: The ILC will explore physics beyond the standard model, such as supersymmetry or composite Higgs models, by making precision measurements of the Higgs boson and top quark. The ILC will search for a class of new particles to which it is sensitive, but which is challenging to detect at the LHC. While searching for such new particles, the necessity of a future ILC energy upgrade scenario will be studied by investigating why the LHC discovers no new particles.

Outcome: If any deviations from the standard model are observed, their size and pattern will elucidate the nature and energy scale of physics beyond the standard model. A big breakthrough is expected if ILC discovers a new particle.

2. Scientific merit of the 250 GeV ILC

- The international community of elementary particle physicists has decided to change the collision energy of the ILC from 500 GeV to 250 GeV. They concluded that this change will reduce the construction cost and better focus the scientific goals of the ILC.
- The Previous Report illustrated the scientific merit of the ILC as follows:

(1) Search for physics beyond the standard model by revealing the whole picture of the Higgs mechanism by detailed studies of the Higgs boson and top quark.

(2) Search for new physics such as supersymmetry, and, if discovered, study it in detailed[6].

(3) Others (dark matter and/or extra dimensions)

- Regarding (1), the strongest advantage of experiments at a 250 GeV ILC is the ability to precisely measure the couplings of the Higgs boson. The Higgs boson may couple to new particles which interact neither strongly nor electro-magnetically, and is therefore expected to couple to dark matter particles and any other particles that evade detection using usual detection techniques. If the precisely measured Higgs couplings are different from the standard model predictions, the particle-by-particle pattern of deviations will elucidate the nature of the new physics. This pattern may suggest the future direction of elementary particle physics. In this way, mysteries of the standard model, such as the

[6] If new physics is discovered at the LHC, the capability of the ILC in terms of its energy reach and the expected precision of its measurements should be examined.

nature of dark matter and whether the Higgs boson is elementary or composite, might be elucidated by precision measurements of the Higgs coupling constants.

- In addition to the production cross section of the Higgs particle being at a maximum at around 250 GeV, the non-observation of new particles at 13 TeV LHC ensures that effective field theory can be used to extract precision Higgs couplings[7], further clarifying the ability of 250 GeV ILC to make precision Higgs measurements.
- On the other hand, reducing the collision energy from 500 GeV to 250 GeV, precludes the measurement of the triple Higgs coupling (using the reaction in which a Higgs boson produces two Higgs bosons), which is specified in the Previous Report as an important physics goal of the ILC project[8]. Neither can precision measurements of the top quark, which require a collision energy of 350 GeV, be carried out at the 250 GeV ILC[9].
- As for (2), based on the results of LHC experiments obtained by the end of 2017, the probability for strongly-interacting supersymmetric particles to exist in the mass range 1.5-2.0 TeV is considered to be very low. According to a theoretical argument on the relation between strongly-interacting and non-strongly-interacting supersymmetric particles, if the former were discovered at the LHC, the latter could be directly detected at the 500 GeV ILC. Non-observation of the former particles[10] at the LHC suggests that the discovery potential is now limited at the 500 GeV ILC, and is even smaller at the 250 GeV ILC.
- In general, experiments at an electron-positron collider are sensitive to particles which are challenging to detect at proton-proton colliders such as the LHC. The chance to directly produce new particles the 250 GeV ILC is low, but they can be studied indirectly through precise measurements of Higgs coupling constants and radiative corrections[11].

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[7] The total decay width of the Higgs boson, which is an indispensable parameter in measuring precisely the coupling constants, was considered difficult to determine at the 250 GeV ILC. However, in the energy range well below the mass of new particles, an approximate calculation based on effective field theory was found to be applicable to the determination of the total decay width.

[8] If the triple Higgs coupling constant is different from the standard model prediction by an unexpectedly large amount, the effect could be observed at the 250 GeV ILC by precisely measuring the coupling constants of the Higgs boson to the Z boson.

[9] The improved top quark mass measurement expected at the upgraded LHC (HL-LHC) is expected to allow us to test the stability of the standard model vacuum. Consequently, the significance of an ILC energy upgrade to 350 GeV for the precision top quark measurement may be less compelling.

[10] If the LHC discovers strongly-interacting supersymmetric particles, a typical supersymmetry theory suggests that the mass of the lightest supersymmetric particle will have approximately one seventh of their mass, although the theoretical uncertainty is not so small.

[11] According to the uncertainty principle of quantum mechanics, a system is allowed to be in a high energy state for an extremely short time. Consequently, the effect of heavy particles can be studied at low energy by observing rare decays that occurs through an ultra-high energy intermediate state.

- As for (3), the capability of the ILC to search for dark matter and extra dimensions will not be significantly reduced at 250 GeV, because these searches are based on indirect methods[12] such as measurements of invisible decays of the Higgs boson, mono-photon events, and radiative corrections to the pair-production of standard model particles.

3. The scenario of the 250 GeV ILC based on the results at the 13 TeV LHC, and related issues

- From the scientific point of view, the scenario of the 250 GeV ILC based on the results of 13 TeV LHC is as follows:

> The scenario of the 250 GeV ILC based on the results of 13 TeV LHC (from the viewpoint of scientific merit)
>
> Plan: Precisely measure coupling constants of the Higgs boson to other elementary particles, and look for clues to clarify physics beyond the standard model. In addition, search for dark matter, extra dimensions, etc. mainly by means of indirect methods.
>
> Outcome: If any deviations from the standard model are observed in the Higgs couplings, their size and pattern will elucidate the nature and the scale of new physics. If observed, dark matter and/or extra dimensions will lead to a big breakthrough.

- On the other hand, the 13 TeV LHC results suggest that discovery of a new particle through direct searches is unlikely at the ILC. It should also be noted that the change from 500 GeV to 250 GeV makes it impossible to carry out precision measurements of the top quark.
- The scenario above should be evaluated together with the ILC project cost estimate to be shown by the TDR-validation Working Group.

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[12] Since the initial state energy is precisely known in electron-positron collisions, the mass of dark matter particles or particles related to extra dimensions could be determined by calculating the missing energy and momentum for the visible system of particle(s) emitted in the opposite direction of these new particles.

Vision of 500 GeV ILC based on 13 TeV LHC

※The scenario in the red box turned out to be the case based on the results from LHC experiments.

Change in scientific merit of 500 GeV ILC, based on experiments at 13 TeV LHC, and international momentum	Change after results from 13TeV LHC						Remarks *BSM: Beyond Standard Model
	Scientific merit of ILC			International momentum of ILC			
	up	same	down	up	same	down	
1. Search for BSM by precision measurements of Higgs boson and top quark							
New particles are discovered at LHC	◆	◆			◆		New physics is unraveled by measuring new particles precisely. Deviation from BSM is expected to be observed at ILC. Scientific merit is up or same according to different arguments. Momentum is shared by LHC and ILC.
No new particles are discovered at LHC	◆	◆		◆			Scientific merit goes up because ILC provides the unique opportunity. Other argument asserts that scientific merit does not change. If momentum for LHC goes down, momentum for precision measurements at ILC goes up.
2. Study of new physics by the direct search for BSM particles such as SUSY particles							
New particles are discovered at LHC, however, direct detection of other related new particles at ILC is unlikely.			◆		↔	↔	Energy upgrade is eventually needed. It was pointed out that ILC keeps momentum if direct detection of new particles is anticipated at ILC with energy upgrade.
New particles are discovered at LHC, and direct detection of other related new particles is probable.	◆			◆			Scientific merit of ILC is huge in elucidating nature of new particles. International momentum goes up.
No new particles are discovered at LHC.			◆	↔	↔		Mass region is narrowed for new particles that are searchable at ILC. With no hints for new particles, ILC is said to have a chance to discover new particles. As ILC and LHC are sensitive to different type of new particles, international momentum goes up or remains at the same level.

either conbination

(1) According to a typical supersymmetry theory, if the LHC discovered strongly-interacting supersymmetric particles, mass of the lightest particle is estimated to be approximately one seventh of them, although the theoretical uncertainty is not so small.

(2) The mas reach of LHC is 2 TeV. New particles with mass up to 250 GeV can be searched for directly at 500 GeV ILC. (No strong-interacting new particles were discovered at 8 TeV LHC.)

Appendix 2

Scientific merit of 500 GeV ILC (original plan) and 250 GeV ILC (revised plan)

Expected scientific merit at 500GeV ILC [as of the Previous Report published in March 2015]		Expected scientific merit of 250 GeV ILC based on results obtained at 13 TeV LHC.					Remarks (Change in the scientific significance) *SM: Standard Model *BSM: Beyond Standard Model
Physics to be explored (Descending order of scientific merit)	Observables at experiments	Search/ verification		Change in scientific merit			
		(for reference) 500GeV	250 GeV	up	same	down	
(1) Search for new physics by measuring Higgs boson precisely	Higgs coupling constants ・quarks (other than top) ・charged leptons ・gauge bosons	feasible	feasible	◆			・Based on the results of LHC experiments, significance of ILC, as a tool to explore BSM, has been increased. ・Search for BSM is possible with precision measurement of Higgs boson because its maximum production cross section is at 250 GeV. ・The total decay width of Higgs boson, which is an indispensable input to precision measurement of coupling constants, turned out to be determinable by using the effective field theory at an energy range below the threshold of new particles. ・Although triple Higgs coupling cannot be measured at 250 GeV ILC, the effect could be observed in the precision measurement of coupling to Z boson, if the deviation from the SM is large.
(2) Direct detection of new particles	Supersymmetric particles Extended Higgs particles	less probable	much less probable			◆	・Based on the non-observation of new particles at 13 TeV LHC, the chance for discovering other theoretically related particles turned out be diminished.
(3) Indirect search for dark matter & extra dimensions	Missing energy & missing mass in mono-jet and/or one-photon events	feasible	feasible		◆		・Indirect search for dark matter and extra dimensions is feasible by measuring invisible decay, one photon events and radiative correction for pair production into SM particles.
(4) Vacuum stability in the standard model	Precision measurement of top quark mass	feasible	impossible			◆	・Scientific significance of the measurement of top quark mass, which requires 350 GeV and controls vacuum stability in the SM, is diminished because the precision of the measurement at LHC experiments is expected to be improved.

(2) Validation of Cost Estimation and Technical Feasibility

Validation of Cost Estimation and Technical Feasibility

The TDR-validation WG (hereinafter "TDR WG") has scrutinized the cost estimation method and technical feasibility described in the Technical Design Report (TDR) of the International Linear Collider (ILC) project and completed a report (hereinafter "the Previous Report") in March 2015. Based on the Previous Report, the ILC Advisory Panel published a document (hereinafter "Discussions to Date") in June 2015. The collision energy of the ILC was then set at 500 GeV (giga electron volt[1].)

Since then, the Linear Collider Collaboration (LCC), an international organization of researchers involved in the ILC, submitted a revised plan[2,3] to the Linear Collider Board (LCB), an international committee for the promotion of the ILC. The LCB has approved[4] the plan and submitted it to the International Committee for Future Accelerators (ICFA). The ICFA endorsed the revision[5] and made a public announcement in November 2017. The revised plan proposes a 250 GeV ILC, based on results obtained in the experiments at 13 TeV LHC, together with the efforts of the LCC toward cost reduction. In response to the revised plan, the Advisory Panel, which took place in December 2017, reconvene the TDR WG to re-examine the method of cost estimation and technical feasibility from experts' viewpoint. The TDR WG held five meetings since January 2018 to revisit the Previous Report and completed this report.

1. Outline of the revised plan of the ILC presented at the TDR WG

1-1. The revised plan proposed by the international community of elementary particle physicists.

- According to the Machine Staging Report[2] published by the LCC, the ILC is redefined as a project carried out in phases. The first phase, including a 250 GeV ILC accelerator and a tunnel to house it, is called Option A, which is the subject of this reexamination.
- The report also defines Option B as a plan with a simple tunnel extension to allow the collision energy to be increased to 350 GeV in the future and Option C with an extension for an upgrade up to 500 GeV. The TDR WG will not examine the Option B and C because the statements issued by the LCB and ICFA propose the 250 GeV ILC as a Higgs factory.

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[1] Electronvolt (eV) : A unit of energy. 1 eV is the energy gain of an electron accelerated by one-volt gap. 1eV is equivalent to a mass of 1.782 x 10^{-33} g.
[2] The International Linear Collider Machine Staging Report 2017, LCC, October, 2017
[3] Physics Case for the 250 GeV Stage of the ILC, LCC Physics WG, October, 2017
[4] Conclusion on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community, LCB, 8th November, 2017, Rev.1
[5] ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory (Ottawa, November, 2017)

1-2. Cost reduction based on R&Ds

- Option A' is based on Option A incorporating maximal cost reduction anticipated by the R&Ds for cost reduction either in progress and in preparation.

1-3. Civil engineering and architecture

- The tunnel length is changed from 33.5 km for 500 GeV to 20.5 km for 250 GeV (Option A and A'). Thickness of a dividing wall at the center of the tunnel is reduced from 3.5 m to 1.5 m in exchange of tighter safety regulation, which limits access to the tunnel during the accelerator operation. Cross section of the tunnel is reduced from 11 m to 9.5 m in width. These changes are reported to contribute to a reduction of construction cost.
- The revision included not only the accelerator but also civil engineering and construction. A major change is in the access to the interaction point for physics experiments and detector installation. A horizontal access tunnel at the beam interaction region was replaced with a vertical shaft and the working efficiency is expected to be improved by using a crane for the installation of detectors and other equipment.

1-4. Labor cost

- As a consequence of reduced length of the accelerator, the necessary workforce is revisited and estimated at 17,165 k person-hours, to be compared with 22,892 k person-hours in the TDR.

2. Cost summary of the revised ILC project presented at the TDR WG

- The construction cost of the revised 250 GeV ILC is estimated at 735.5~803.3 billion-yen (635.0~702.8 billion-yen for the accelerator and 100.5 billion-yen for the detectors and related expenditure.) Additional expenses may arise from an inaccuracy in the cost estimation and the risk factors and unforeseeable technical issues described in Section 3.
- While an inaccuracy of about 25 % of the total construction cost of the accelerator and detectors is taken into account, it should be noted that the inaccuracy does not include technical risks nor extension of construction period nor change in market prices.
- The annual operation cost is estimated at 36.6~39.2 billion-yen. A supplementary cost in a preparatory phase is estimated at 23.3 billion-yen. An additional cost, such as a site-specific expenditure, may add up.

- The contingency, a reserve for unforeseeable expenditure, is estimated at about 10 % of the project cost (construction of the accelerator and detectors, and the operation.) The cost of decommissioning is newly estimated to be equivalent to the cost of two years of operation.

Breakdown of the cost presented at the TDR WG is the following.

(Premises)

The ILCU, a virtual currency unit, is used in the cost estimation. Based on the purchasing power parity (PPP), 1 ILCU is defined as 1 USD as of January 2012. Allowing for an international bidding, the cost in Japanese yen (JPY) listed below assumes an exchange rates of 1 Euro (EUR) = 115 JPY and 1 USD = 100 JPY.

A range of estimation reflects a recent price rise in the construction business after the completion of TDR due to the recovery and reconstruction from the Great East Japan Earthquake and the preparation of Olympics 2020 in Tokyo. The cost of the accelerator construction and operation may also change depending on the results of the R&D pursuing cost reduction. The same currency exchange rate is used as in the TDR for a simple comparison. Labor cost, which was estimated with person-hour, was transformed into JPY.

* A comparison between 500 GeV ILC (original plan) and 250 GeV ILC (revised plan) is summarized in the appendix.

(1) Accelerator construction Subtotal: 635.0～702.8 billion-yen (ref. TDR)

Civil engineering and architecture 111.0～129.0 billion-yen (Civil Construction)

Accelerator 404.2～454.0 billion-yen (SRF and other acc. utilities etc.)

Labor 119.8 billion-yen (equivalent to 17,165 k person-hours)

(2) Detectors Subtotal: 100.5 billion-yen (ref. TDR)

Detector construction 76.6 billion-yen

Labor 23.9 billion-yen (equivalent to 3,651 k person-hours)

(3) Inaccuracy Subtotal: 25 % of (1) and (2) (ref. TDR)

* Inaccuracy is defined as what arises from uncertainty in the cost estimation, not from technical risks, delay in schedule and variation of market prices.

(4) Operating cost 36.6 ~ 39.2 billion-yen/year (ref. TDR)

Utilities and maintenance 29.0 ~ 31.6 billion-yen

Labor 7.6 billion-yen (equivalent to 638 persons per year)

(5) Other expenditures (not specified in TDR)

Expenditure in a preparatory phase 23.3 billion-yen

(Including design, R&D, environmental assessment, training, technology transfer, management and administration)

Items whose cost have not been estimated in the TDR are; land acquisition, living environment for overseas researchers, access road, construction waste disposal, groundwater handling, an energy service enterprise for power transmission [6] and substations, low voltage power supplies, infrastructure such as lifeline, computing center.

(6) Contingency About 10 % of the total project cost (the accelerator, detectors and operation[7]) (ref. PIP[8])

* A reserve fund for unexpected expenditure.

(7) Decommission Equivalent to 2 years of annual operating cost (not specified in TDR)

* Expenditure for decommissioning what have been installed and assembled in the construction period. Accelerator components are assumed to be re-used, for which storage facilities on the ground should be prepared.

The construction costs listed above in (1) to (7) have been estimated by the proponents. It should be noted, however, an additional cost may arise from risk factors and technical issues listed in Section 3.

3. Risk factors and technical issues

In the Previous Report, various issues have been pointed out on the premise that the technical issues are resolved and necessary human resources are secured in a 4-year preparatory phase[9] prior to the construction.

[6] Energy service enterprise is an enterprise to be outsourced to an outside company for facility construction and operation. Initial and operation cost can be leveled in a long-term basis.

[7] (4) (Annual operation cost) x (Years of operation) (More than 20 years is assumed in PIP)

[8] Revised ILC Project Implementation Planning, Revision C, LCB, July 2015

In response to the above comment, KEK completed the KEK-ILC Action Plan (published in January 2016) as a basis of further consideration of technical issues, organizational structure and arrangement, and plan for human resource preparation and training. Based on this Plan, KEK will conduct a detailed study and demonstrate technical feasibility in a 4-year period of preparation. KEK estimates a cost of the preparatory phase at 23.3 billion-yen including some overseas contribution.

In not a few areas described in detail below, such as accelerator technologies, tunnel construction and earthquake countermeasures, the original specification and/or planning should be modified in the course of construction reflecting up-to-date circumstances. In order to contain a possible cost-overrun, the proponents have studied various situations and the TDR WG has scrutinized their study in detail. However, due to the intrinsic nature of the issues, it is difficult to make a reliable estimation in prior to the construction. Consequently, the estimated values for those issues are not shown in the following sections. Therefore, we should keep in mind that a possible large cost-increasing may occur in a certain situation.

3-1. Responses to the Previous Report and new comments to the responses

Although some countermeasures are being devised for the issues pointed out in the Previous Report, many others have been claimed to require continuing studies in the preparatory period. The progress and comments presented at the TDR WG are listed below.

3-1-1. Risk in cost estimation

- A US-Japan collaboration is conducting a R&D to pursue cost reduction of the "superconducting RF cavities focusing on low-cost niobium material"[10] and "surface treatment for low-loss and high-gradient cavities."[11]
- It is pointed out in the Previous Report that procurement of high-purity and high-quality niobium in a large amount could be an issue. The quantitative burden has been mitigated in the revised plan with a reduced number of cavities, 9,000 instead of 18,000. A new manufacturing procedure is under study to make a niobium sheet by

[9] KEK-ILC Action Plan defined 3 phase as the project evolves; pre-preparation, main preparation and construction.

[10] Refining cost could be reduced by optimizing the purity and Residual-resistance Ratio (RRR) of niobium material. In the refining process, some manufacturing processes such as forging, rolling and mechanical polishing could be eliminated by directly slicing off the cavity disks from an ingot. This new method is expected to reduce the cost by 1~2 % for the 250 GeV ILC.

[11] A new process developed at the Fermi National Accelerator Laboratory. By introducing nitrogen gas in the heat treatment process of the superconducting cavities, the acceleration gradient will be increased and the power loss can be reduced. The method, called nitrogen infusion, is expected to reduce the number of accelerator components, such as cavities, as well as the cost of refrigerators. In total a cost reduction of 2 ~ 5 % is expected for the 250 GeV ILC.

direct slicing of an ingot. If this method is proved to be practical, the productivity is improved. Hence, a realistic projection is anticipated both in quality and cost-saving in the procurement.

- Four items are added to "2. (5) Other Expenditures" whose cost is not estimated in the TDR, namely construction waste disposal, groundwater handling, an energy service enterprise for power transmission and substations, and low voltage power supplies.
- Preparing for an unexpected situation or cost-increasing, a contingency has been added to 2. (6), as pointed out in the Previous Report, following an assumption in the PIP (as a LCB publication) amounting to about 10 % of the construction cost of the accelerator and detectors plus the operation cost.
- Cost of decommission was added to 2. (7) as a new item. According to the estimation by KEK, the cost is equivalent to the operation cost for 2 years. The accuracy needs to be improved, and the cost sharing among international partners should be discussed including a case of cost overrun.
- Considering the ILC being a long-running project, an additional cost increase, due to personnel aging and companies pulling out of the project, should be taken into account.

3-1-2. Technical feasibility

- After the Previous Report, the European X-ray Free Electron Laser (E-XFEL), a project of one tenth scale of the ILC, started user operation in September 2017, demonstrating the technical feasibility of superconducting accelerator technology. However, the construction cost calculated at the completion of the accelerator, except for preparation and commissioning, turned out to exceed the estimation in the E-XFEL TDR by about 10%. The cause of the increase should be investigated and reflected in an improved estimation to be carried out in the preparatory phase.
- As pointed out in the Previous Report, there remain issues on several components/systems such as beam dumps, positron source, electron source, beam control and injection/extraction of damping rings, which are not well demonstrated.
- Although the change in collision energy from 500 GeV to 250 GeV has relaxed some technical requirements, increasing the likelihood of a design of the beam dump, all the technologies underpinning the whole beam dump system should be developed in the preparatory phase. The required technologies include durability of the window, where continuous high-power beam pass through, and its maintainability and resistance to earthquakes.
- The helical undulator scheme is adopted as the positron source. It contains some technologies under development such as the cooling of the target irradiated by the

gamma rays from the undulator and the replacement method of the activated target. Technology choice should be done including the consideration of the development cost.

- Since ILC is a huge and complex accelerator system and performance to withstand long-term stable operation is required, it is important to provide prospect of technical feasibility during the preparation period.

3-1-3. Acquisition of talents for construction, operation and management

- After the Previous Report, a separate working group was launched to investigate the acquisition of talents and the Advisory Panel has published a report, the Report on the Human Resource Development in July, 2017.

3-2. Items discussed in detail at the TDR WG

The TDR WG has discussed the following items as well as the issues pointed out in the Previous Report. Risks have been estimated referring to legal regulations, which will be applied in case of the construction and operation in Japan, and precedents. A report on research and analysis carried out by outsourcing was also utilized[12].

3-2-1. Civil engineering (Underground structures, experimental hall cavern, and access tunnel/ vertical shaft, etc.)

- A huge amount of soil/muck will be produced during tunnel excavation. The disposal method and site of soil/muck should be prepared in an early stage of construction. In particular, when heavy metals are contained in excavated rock, it is necessary to consider the disposal method and to consult with related organization.
- As the access portal to the tunnel is constructed at the surface of the earth, it has a great impact on the environment during the construction and operation. Therefore, a preparatory investigation on the environmental impact in the vicinity of the access portal and soil/muck disposal site should be carried out prior to the construction. A countermeasure should also be developed against a collapse of slope and landslide disaster around the portal site.
- Due to the change in the thickness of the separation wall, from 3.5 m to 1.5 m, access to the RF power supplies for maintenance during beam operation is not allowed. Therefore, a new procedure should be devised.

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[12] Research and A8nalysis on Regulations ad Risks for ILC project, Nomura Research Institute, February 2018.

3-2-2. Radiation safety

- On the assumption that a beam loss is small, a 30cm thick tunnel lining is estimated to be sufficient to prevent activation of soil and groundwater from the beamline. It is therefore important to improve reliability of the accelerator, its control system and beam loss monitors.
- Decommissioning process after the completion of experiments has not yet been considered in detail at this moment, however, a long-term plan for the maintenance and storage of cavities and experimental apparatus including beam dumps with radioactivity should be devised. It is essential to gain a full understanding of local residents by scientific reasoning together with proper waste disposal.

3-2-3. Earthquake countermeasure

- There is no law nor regulation in Japan that stipulates countermeasures for an underground structure against earthquakes. However, a safety measure, such as the Building Standards Law, intended for a building on the ground may possibly be applied to an underground structure, for example, the experimental hall and its surroundings where visitors may walk around. Even if the safety measure is not applied, it should be noted that a similar standard may be applied depending on an agreement with the local authority.
- Seismic performance of the underground facilities is secured by applying a guideline established by the Japan Society of Civil Engineers[13]. Taking into account of recent cases of tunnel damage caused by big earthquakes, reinforcement work is considered to be done to prevent the damage and peeling off of the lining concrete. These countermeasures should be securely carried out.
- Not all the potential geological problems can be avoided because the ILC tunnel is so long that the ground is not necessarily a solid and homogeneous bedrock. The facilities and equipment have a possibility to be located near faults or weak layers and the groundwater flow rate is possible to change due to earthquakes. Therefore, the detailed site study is essential and the design of underground structures should be carried out accordingly.

[13] A Guideline for Civil Construction of the ILC Project, Committee on Rock Mechanics, Japan Society of Civil Engineers, March 20

- The main linac tunnel should be designed to secure stability against earthquake and to maintain the basic functions such as drainage, ventilation, lighting, passage and communication at the time of earthquake.
- Further detailed studies should be made for the facilities and equipment that have not yet been concretely studied in the seismic performance.

3-2-4. Mountain Spring water measure

- The ground condition may not be well understood prior to tunnel excavation. There is a risk in the construction cost and period when confronting unexpected phenomena such as bedrock falling and a large amount of spring water.
- In case that the spring water is contaminated by heavy metals, a particular attention should be paid on additional cost and a plant that locates and isolates the contaminated water, which is not allowed to be drained as it is, for proper treatment.
- The current cost estimation is based on an assumption that the groundwater comes out uniformly, while the groundwater flow in a granite region might be localized and subject to temporal variation. There is a risk of additional cost for disposal facilities and installation.

3-2-5. Environmental impact

- The majority of the ILC facilities are built in an underground space and consequently the range of application of The Environmental Impact Assessment Law is considered to be limited compared with ground facilities. However, thorough environmental assessment and explanation to the public should be made along with abiding relevant laws because the ILC facilities have a great environmental impact during construction and operation period.
- The ILC facilities are assumed to be located in a solid and homogeneous granite bedrock without any nearby active faults. However, the groundwater flow may change due to the construction of the underground space and the underground water level may be lowered in a large area. Therefore, during the construction, the impact of construction needs to be understood by careful investigation of vegetation and ecology, and water volume of streams and swamps.
- Although an ordinary environmental assessment takes 3 to 5 years, it should be noted that a longer period is needed in cases due to unexpected issues.

Appendix 1

The ILC project cost for 500GeV ILC and 250GeV ILC presented at the Hearing

Item		500GeV ILC (original plan)	250GeV ILC(revised plan): Cost estimation presented at the TDR WG	250GeV ILC(revised plan): Option A (250GeV ILC as a Higgs factory)	250GeV ILC(revised plan): Option A' (Incorporated results from cost reduction R&D)
※The cost-estimate listed below in (1) to (7) is a summary reported by the research community. It should be necessary to pay attention to additional cost risk possibly caused by the risk factors and technical issues described in the Section 3, in this TDR-WG report.					
Construction of the ILC accelersator and detectors	(1) Accelerator (2) Detectors	1,091.2 billion-yen	735.5～803.3 billion-yen	785.3～803.3 billion-yen	735.5～753.5 billion-yen
			(3) An additional cost arising from inaccuracy and items described in the Section 3 of the report may be added.		
(1)Accelerator（ref. TDR）【revised】		990.7 billion-yen	635.0～702.8 billion-yen	684.8～702.8 billion-yen	635.0～653.0 billion-yen
	Civil engineering and constru	160.0 billion-yen (Civil engineering + Acclerator construction: 830.9 billion-yen)	111.0～129.0 billion-yen (Civil engineering + Acclerator construction: 515.2～583.0 billion-yen)	111.0～129.0 billion-yen	111.0～129.0 billion-yen
	Acclerator construction	670.9 billion-yen	404.2～454.0 billion-yen	454.0 billion-yen	404.2 billion-yen
	Labor	159.8 billion-yen	119.8 billion-yen	119.8 billion-yen	119.8 billion-yen
(2)Detectors and related expenditures（ref. TDR）【No change】		100.5 billion-yen	100.5 billion-yen	100.5 billion-yen	100.5 billion-yen
	Detector construction	76.6 billion-yen	76.6 billion-yen	76.6 billion-yen	76.6 billion-yen
	Labor	23.9 billion-yen	23.9 billion-yen	23.9 billion-yen	23.9 billion-yen
(3)Uncertainty（ref. TDR）【No change】		About 25% of (1)+(2)	About 25% of (1)+(2)	About 25% of (1)+(2)	About 25% of (1)+(2)
	※Inaccuracy: Only the inaccuracy in the cost estimation is included. What is not included are technical risks, extension of construction period and change in market price.				
(4)Operation（ref. TDR）【revised】		49.1 billion-yen	36.6～39.2 billion-yen	39.2 billion-yen	36.6 billion-yen
	Unitilities and maintenance	39.0 billion-yen	29.0～31.6 billion-yen	31.6 billion-yen	29.0 billion-yen
	Labor	10.1 billion-yen	7.6 billion-yen	7.6 billion-yen	7.6 billion-yen
(5) Other expenditures（not in TDR）					
	Preparatory cost (Design, R&D, Environmental assessment, training, technology transfer, management and administration, including labor cost)	Not estimated	【New estimation】 23.3 billion-yen	23.3 billion-yen	23.3 billion-yen
	Not estimated in TDR	Not estimated	Not estimated	Not estimated	Not estimated
	land acquisition, living environment for overseas researchers, access road, infrastructure such as lifeline, computing center		【New estimation】 Waste and spring water disposal, power transmission and substations, low votage supply		
			(6)Contingency	About 10% of project cost (accelerator+detectors+operation*)（ref. PIP）	
			【New estimation】 Reserve fund for unexpected expenditure.	*annual operation cost x operation years	
			(7)Decommissioning	Equivalent to 2 years of operation.	
			【New estimation】 Accelerator components will be re-used, for which storage facilities should be prepared.		

(3) Validation of Human Resource Development

Validation of Human Resource Development

To identify human resource–related issues for realizing the ILC, the working group examined the human resources as well as the situations inside and outside of Japan with regard to large accelerator facilities. Additionally, the plan to secure and develop the human resources necessary to construct and operate the ILC was verified. The results of these discussions are described in the following sections.

1. Summary of the discussions of the Human Resource Securing and Developing Working Group

Estimated human resources required for the accelerator construction as summarized in the TDR are:

- The construction phase is expected to last 9 years. The average number of personnel required to construct the facility is 830 per year, while that for equipment installation is 378*. (The appendix provides a detailed breakdown of the estimated human resources.)

  * This number is averaged over 7 years beginning in the third year.

- Personnel required to construct the facility will be employed directly by the project implementing body of the ILC (including subcontracted workers). Such personnel will be responsible for designing the accelerator and its components, supervising production, assessing the performance of delivered components, and assembling/adjusting the accelerator. Personnel required for equipment installation will engage in transporting from the ground to the accelerator tunnel and installing accelerator components.
- It is assumed in the TDR that major research institutes for elementary particle and nuclear physics around the world will collaborate and provide human resources with an appropriately balanced distribution.
- The study* conducted after the submission of the TDR estimated that the preparation phase would occur in the four years prior to the construction phase and that 282 core members (34% of the annual average of 830 persons required to construct of the ILC) should be trained during the four-year preparation phase.

  * A detailed discussion can be found in the KEK-ILC Action Plan, which was reviewed mainly by the High Energy Accelerator Research Organization (KEK) and published in January 2016 and addendum issued in January 2018.

2. Current situation for securing and developing human resources for large accelerator projects

2-1. Situation in Japan

2-1-1. Universities and Research Institutes

- In Japan, human resources required to construct and operate large accelerators traditionally have become proficient by on-the-job training (OJT).
- For example, many scientists/engineers were trained during the KEK-PS (Proton Synchrotron) construction in the 1970's and the TRISTAN (Transposable Ring Intersecting Storage Accelerator in Nippon) construction in the 1980's. These scientists/engineers gained valuable experience in conceptual and technical design, manufacturing, assembly, construction, and operational tests of accelerator components, coordination with relevant organizations and factories, and supervision of all procedures as an integrated system. Since then, these experienced scientists/engineers have played a crucial role in promoting accelerator science through their contributions in large accelerator projects.
- However, OJT to train young scientists/engineers is decreasing as opportunities to experience constructions of large-scale accelerator are diminishing. This is partly because each project itself has become relatively longer term and larger scale resulted from advancement of accelerator science.
- Consequently, there are growing concerns about the depletion of human resources to supervise an entire accelerator as an integrated system because operations and upgrades of existing facilities do not provide sufficient opportunities for young scientists/engineers to gain experience in global management of a large-scale accelerator system.
- Moreover, the number of laboratories at universities specializing in accelerator science is decreasing. Although there is a career path where young researchers in relevant fields such as elementary particle and nuclear physics experiments are recruited and trained as accelerator science specialists, personnel exchanges between accelerator science and other fields with similar technical skills have yet to be fully realized.

2-1-2. Industry

- Accelerator construction requires diverse technologies such as electromagnetic field analysis, radio frequency engineering, structural and mechanical analysis, thermal insulation design, precision machining, surface treatment technology, high cleanliness welding, and precision installation and alignment. Accelerator projects are a valuable opportunity for industry to develop human resources responsible for large-scale construction since very few project are likely to employ such a variety of technologies.
- Some of the accelerator components themselves are objects of research. Close communication between industry engineers and researchers should realize quality

manufacturing. Hence, it is important for industry to train engineers to work directly on technology development and performance tests in conjunction with researchers from the prototype phase.

- In order to fully adapt to large-scale projects like the ILC, human resources should be trained systematically with an adequate preparation period and a clear vision of the project.
- To recruit and train industry engineers who can lead accelerator construction, it is important to clarify the prospects for the project, including the schedule of each construction procedure. This will enable companies to develop long-range plans for securing and retaining human resources during and after the project.
- Flexible redeployment of engineers among relevant technical fields should be carried out to cope with the peak period of accelerator construction since the number of industry engineers specializing in accelerator engineering is limited.
- Because Japan's plan for future large accelerator projects is currently unclear, Japanese industry is making efforts to strengthen its international competitiveness by maintaining skilled engineers/technicians and developing advanced technologies through participation in accelerator projects outside of Japan. In addition, Japanese industry strives to maintain its pool of engineers by constantly hiring new engineers/technicians, if at all possible, to avoid a generation gap in technology handovers.
- Accelerator construction requires many specific materials and components compared to other industrial products. Productivity in mass production should improve as both the manufacturing efficiency and quality control advance through greater ingenuity. For this reason, a large number of designers will not be necessary once the mass production line is established, but a considerable number of engineers is required to investigate and resolve unexpected problems in quality control, cost management, and manufacturing procedures.

2-2. International situation

- Similar to the case in Japan, skilled scientists/engineers are trained by OJT in Europe, the United States, and other countries, but the mobility of human resources is higher than in Japan. In these countries, human resources are actively exchanged between public and private sectors as well as different research fields.
- For these reasons, skilled scientists/engineers for ongoing projects are properly trained and secured in foreign countries. However, a clear vision is necessary to ensure the

availability of additional human resources if a new large-scale project is started under international collaboration.

- At the European Organization for Nuclear Research (CERN), there are two types of regular employees: fixed-term staff (five-year term) and permanent staff. Less than half of the fixed-term staff are promoted to permanent core staff at the end of their terms. Furthermore, during the construction period of the Large Hadron Collider (LHC), CERN introduced a system called "Project Associates", where staff from other institutes participated in a project in cooperation with the researchers and engineers of CERN.
- CERN staff dispatched from other relevant institutes are expected to return to their original institutes upon completion of their term at CERN. This requirement is stipulated in their contracts. CERN is not responsible for their next career positions. Since many of the fixed-term staff members of CERN are engineers and applied scientists in various research and technical fields, there are many opportunities with other international organizations after leaving CERN. Thus, this type of employment system does not cause specific problems.

2-3. Relationship to the ILC

- A significant amount of human resources must be engaged domestically and internationally when a large-scale international cooperation project like the ILC is undertaken. Therefore, the introduction of a new employment system to attract human resources internationally is essential. The ILC should refer to CERN's employment system of "Project Associates" since the system functioned extremely well during the LHC construction at CERN.
- Although the estimated annual amount of human resources for the ILC construction is about 830 on average, it will reach 1,200 during the peak construction period. A system capable of handling the maximum number of the required laborers should be established.
- Currently, human resources in Japan are managed for securing research and development of advanced accelerator components, and maintaining existing facilities and equipment. However, it is likely that the available human resources in Japan will be in short supply when the ILC is in the construction phase.
- The first half of the ILC construction phase is the important term for the technological development of the accelerator as the number of elements for development decreases as the construction progresses. It should be noted that the required number and types of personnel varies according to the construction phase.

- Continuously securing and developing skilled personnel is necessary to execute accelerator projects sequentially in Japan. Regardless if the ILC project is implemented, strengthening the base of human resources in accelerator science is critical.
- It is traditional in Japan for a small number of accelerator experts to carry out their assigned responsibilities while simultaneously cooperating with one another for other mutual tasks. On the other hand, some foreign institutes manage entire projects by assigning highly professional engineers as managers to lead projects. A novel system integrating these two styles should be sought when an international cooperation project like the ILC is launched in Japan.
- Furthermore, a system of multilayered management should be organized to monitor and control the technological development, engineering processes, and the progress of the entire system because the management needs to be very sophisticated as the project is scaled up. Therefore, securing trained core managers for each individual layer should be considered.

3. Future issues and near-term action plan

3-1. Development of human resources in Japan

- It is clear that the quantity and quality of the current pool of available human resources in Japan is insufficient to handle a large-scale project like the ILC. Skilled scientists/engineers should be trained and secured in a strategic manner based on an international agreement in order to share the necessary manpower.
- It is necessary to train and secure experts capable of managing large-scale projects, especially if Japan takes a leading role in the ILC. It is also important to establish a risk management procedure to review and conduct the necessary actions based on risk analysis in reference to various experiences integrated in the LHC construction and operation.
- The required amount of human resources increases temporarily during a large-scale project such as the ILC. However, these demands are not permanent, and potential career paths (not only domestically but also internationally) for trained and skilled scientists and engineers after the construction phase must be taken into consideration.
- It is desirable to train and secure accelerator experts who thoroughly understand the entire accelerator system and can develop a flexible framework that adapts to the dynamic changes in the demand for human resources by employing highly qualified engineers in each technical area.
- Existing facilities have ongoing renovations and significant upgrades of accelerator equipment. These projects provide great opportunities to train young scientists/engineers.

- Additionally, when a new accelerator is constructed in Japan, the training of young scientists/engineers during the construction should be a national commitment. It is important to involve the younger generation in the management of the whole system so that they can play leading roles in future projects.

- Furthermore, an accelerator facility network to enhance the exchange of human resources should be considered. Such a network should be designed to intensively provide human resources for a new accelerator under construction in such a way that many scientists/engineers can gain valuable experience. As an example, the cross appointment at two institutes should be utilized as well as existing employment schemes, such as joint affiliation, in order for talented personnel to take responsibility in the project as a member of the organization promoting the new accelerator project.

- It is also important to consider sending young scientists/engineers to foreign accelerator institutes when they execute new construction or upgrades using the aforementioned network. This should help cultivate talent with practical experience.

- Moreover, intensive communication should be promoted among scientists/engineers in different fields whose expertise is required to construct the accelerator system. This will widen the sources of human resources and help establish a management organization where various expert scientists/engineers with accelerator experience work together. It should also be noted that retiring experts with experience promoting large-scale accelerator projects can contribute to the future project by transferring their expertise and technology to younger engineers through collaborative work.

- To train scientists/engineers involved exclusively in each project such as the ILC, the target recruitment plan will be settled when the concrete schedule of the project is determined. However, realizable human resource development issues should be addressed promptly as this will help consolidate the foundation of human resources and continuously promote future accelerator projects in Japan.

3-2. Human resources from abroad

- It is assumed that there will be close negotiations with partner institutes abroad in order to share the human resources required for the ILC project. It is important to accommodate the human resources provided by these institutes. To develop feasible resource sharing plans, the availability of such human resources and assignment duration should be taken into account.

- Furthermore, if many non-Japanese scientists/engineers are to be involved, consideration in cooperation with local communities should be given to establish a comprehensive supportive environment for housing, daily life with family members, and coordination of salary and working conditions, especially considering the disparity in such conditions between Japan and their home countries.

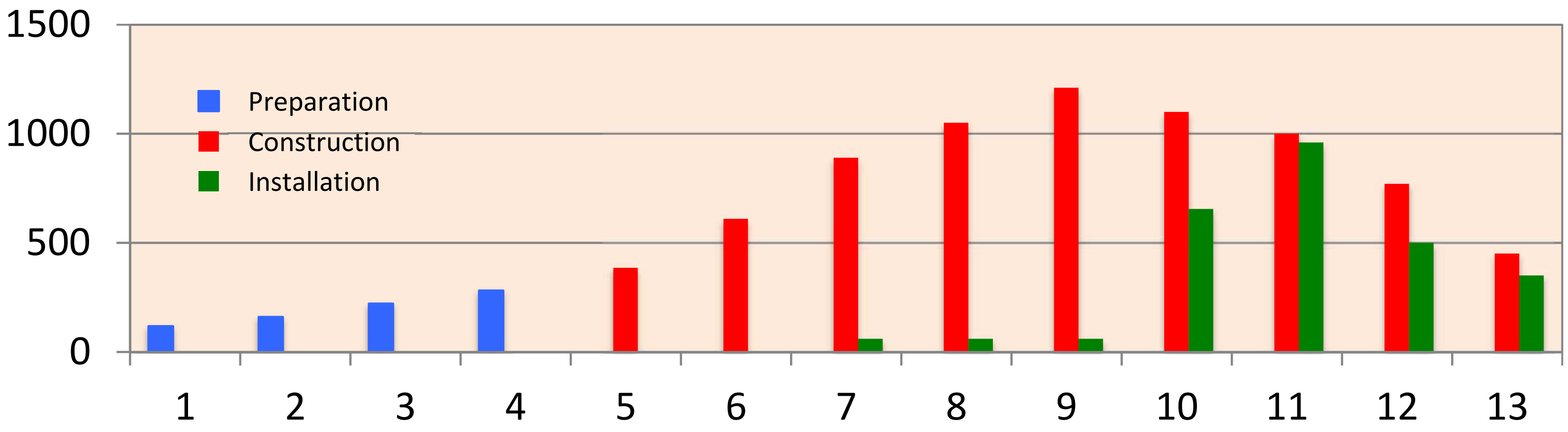
[Appendix]

Overview of Human Resources during the ILC Construction

Preparation stage (4 years) ~ Construction stage (9 years) ILC-500 → ILC-250

unit: person

Stage	Preparation				Construction									Total
	1	2	3	4	1	2	3	4	5	6	7	8	9	
Prep.	118	161	222	282										
TDR							TDR, ILC-500 Ann. average: ~ 1,100 persons							
Constr.					410	922	1208	1350	1589	1480	1374	1106	679	10,118
Install.							80	80	80	768	1140	683	522	3,353
Total					410	922	1288	1430	1669	2248	2514	1789	1201	13,471
ILC-250							ILC-250: Ann. average: ~ 830 persons							
Constr.					**385**	**610**	**890**	**1050**	**1210**	**1100**	**1000**	**770**	**450**	**7,465**
Install.							**60**	**60**	**60**	**655**	**960**	**500**	**350**	**2,645**
Total					**385**	**610**	**950**	**1110**	**1270**	**1755**	**1960**	**1270**	**800**	**10,110**



(4) Validation of Organization and Management

Validation of Organization and Management

This latest working group reviews the organizational and managerial aspects of the international institution which researchers plan to establish for the ILC project as well as surrounding infrastructure and environment. It also studies what would be a suitable domestic organizational structure should the collider be built in Japan.

1. Researcher community reports to working group

1-1. Organization and management of an international laboratory

The Linear Collider Board (LCB), an international organization set up to promote linear collider projects such as the ILC, published the following report on the organizational structure and management of an international laboratory for the ILC project:

1) Revised ILC Project Implementation Planning (PIP) Revision C (July 2015, LCB)

This PIP is supplemented by the following two documents, which cover preparatory work to do before the start of the project:

2) Project Design Guideline toward ILC (PDG) (Sept. 2012, ILCSC*)

* ILCSC, the International Linear Collider Steering Committee (LCB's predecessor)

3) KEK-ILC Action Plan (Jan. 2016, KEK*)

* High Energy Accelerator Research Organization

The overall schedule of the ILC project, the organizational structure, and management at each stage of the project assumed in the above reports are as follows:

Overall schedule

1) A *pre-laboratory organization (pre-lab)* will be established based on agreements with the approval of the respective governments among participating institutions to finalize engineering design and segregate duties among participating entities for the first four years. This pre-lab is then to be succeeded by 2) the *ILC Laboratory*, a treaty organization responsible for the some nine years of construction*. After this, 3) an *international collaboration group* will run experiments for two decades or more.

* The PIP specifies an eight-year construction period, but Global Design Effort's technical design report (TDR) assumes nine years, including tunnel boring and adjustments, followed by a one-year commissioning period for the accelerator. Gathering of experimental data would begin in the 11th year.

1-1-1. Pre-lab

- The PDG looks at five different models (M1 to M5) of organizational and managerial structures for the ILC preparatory organization from the perspectives of legal basis, employment pattern, and procurement. While many details still need to be sorted out, the PDG recommends starting with M4, a model based on agreements among participating institutions, then to transition to M3 or M5, a multi-national research institution based on an international treaty.

M1: A treaty-based organization. The employment and procurement are financed by in-cash contributions from participating entities (CERN* type)

* CERN: European Organization for Nuclear Research

M2: A limited liability company financed by a combination of in-cash and in-kind* contributions (European XFEL† type).

* in-kind: including labor

† XFEL: X-ray Free Electron Laser

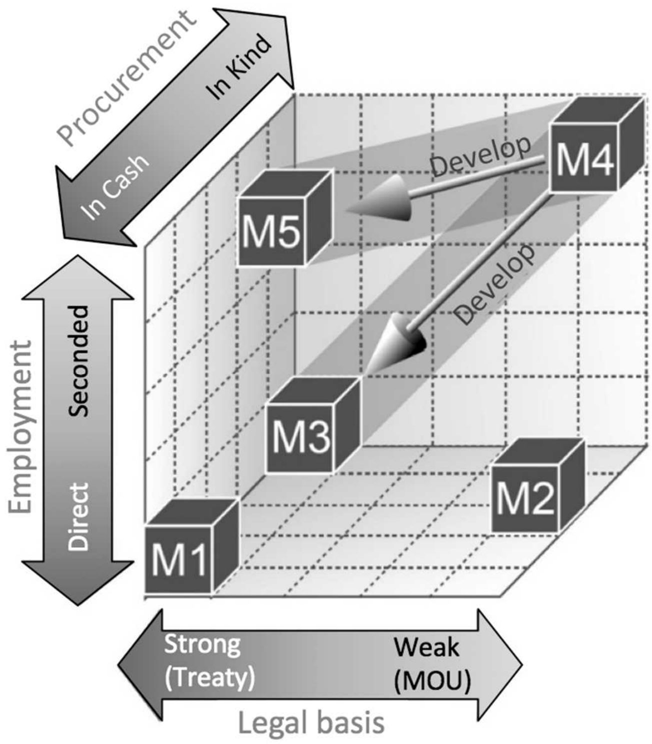
M3: A treaty-based organization. Materials are supplied in-kind and core organizational staff are employed by a common fund (ITER* type).

* ITER: International Thermonuclear Experimental Reactor

M4: An organization based on agreements concluded among participating institutions, which supply materials in-kind and second human resources, as in multi-national research institutions.

M5: A treaty-based organization evolved from M4 with a strong legal basis.

Figure: Conceptual view of the ILC organization transition



Source: PDG

- In the event Japan hosts the ILC, the KEK-ILC Action Plan recommends establishing a pre-lab based on agreements among participating institutions, with headquarters located at the KEK, then finalizing design and segregating duties among participating entities within four years.

- The KEK-ILC Action Plan estimates the number of personnel on the pre-lab to be about 200, of which 20% to 40% are expected to come from overseas institutions. The pre-lab will have to provide training for the employees to build up their capacity for project management, quality control, performance evaluation as well as the technology verification necessary for mass-production of superconducting cavities.

1-1-2. ILC Laboratory

- The PIP assumes the following regarding the organization and management of the ILC Laboratory (composed of about 830 members*):

  * The required number of personnel during the ILC's construction period is estimated in the TDR, and the average is 830 per year.

[Legal basis]

- The following terms are to be stipulated in an international treaty:
  - exemption from VAT, import tariffs, and similar privileges;
  - the rights and obligations of the host state;
  - decommissioning procedures and responsibilities.
- The treaty prohibits withdrawal of member states for 10 years, assuming nine years of construction and 20 years of operation, and requires two years notice of withdrawal beginning the 11th year.

[Top management]

- The ILC Laboratory Council, the ultimate decision-making body composed of two official delegates from each member state, decides by a simple majority vote except for financial agenda items, which are decided by a qualified majority vote depending on financial contribution. Council delegates must be of sufficient standing in their respective governments to facilitate prompt decisions.
- The council appoints the director-general after a full and open search and delegates to him/her significant authority and responsibility for the management of the ILC Laboratory.
- The ILC Laboratory Directorate, selected by the council, executes financial and administrative affairs under the director-general.

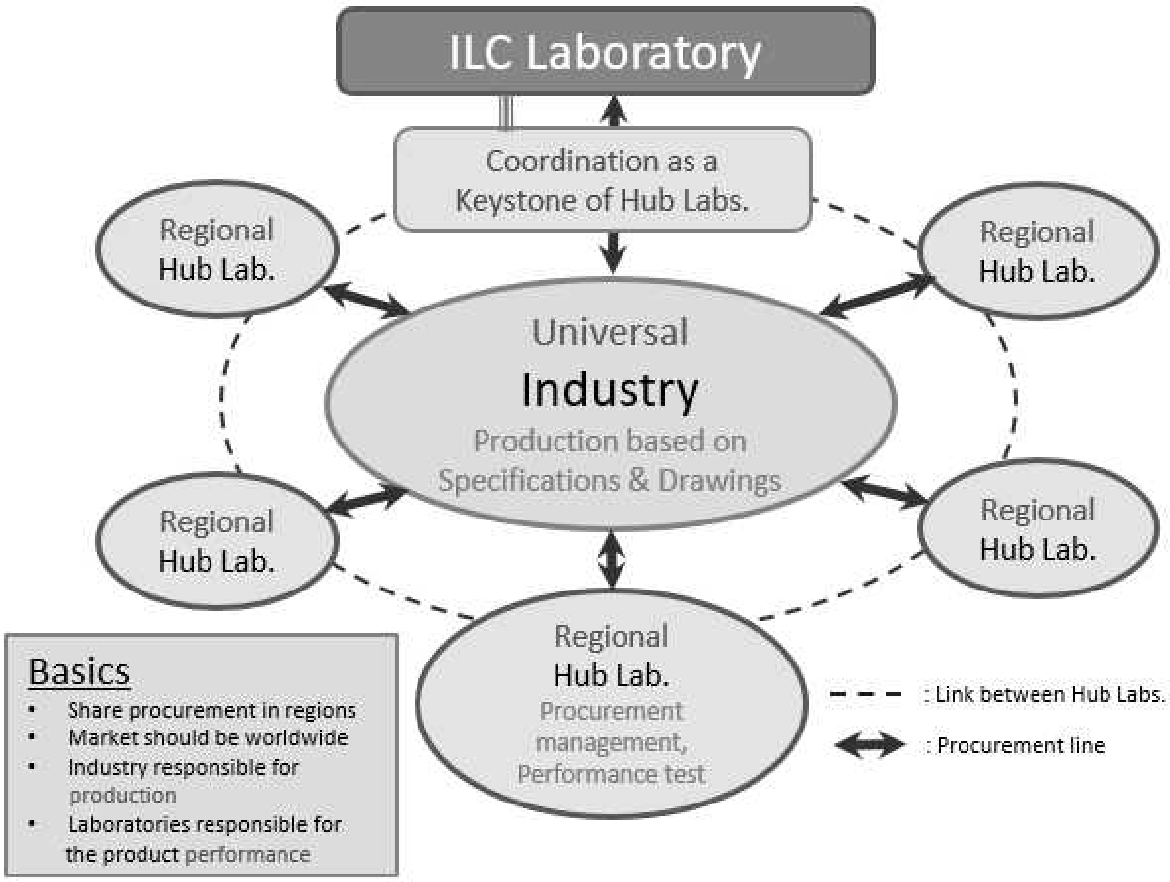
[Project management]

- The ILC Laboratory Central Project Team is responsible for the accelerator's design, one that is compatible with the selected construction site, and specifications for equipment contributed in-kind by participating countries.
- Participating countries are responsible for cost containment and the delivery on schedule of its in-kind contributions.

[Management of accelerator construction]

- A hub laboratory in each region coordinates the construction of the accelerator and its components, divided among international partners as per their in-kind contributions, based on contracts with corporations selected through a bidding process.
- Contractors are responsible for the product on a build-to-print basis, based on the specifications and fabrication drawings indicated in the contract. The product must pass an international standard inspection at delivery.
- The hub laboratory, or a consortium of collaborating institutes, guarantees the performance of the product by conducting a comprehensive test of the electric field gradient, the cavity's resonance characteristics, and other prominent product features.
- The hub laboratory can produce prototypes and verify technology. It is expected to mitigate risk for vendors by transferring technology and data after establishing a manufacturing process.
- The ILC Laboratory serves as a central hub connecting hub laboratories and supervises the entire supply chain.

Figure: International procurement of ILC components



Source: PIP

[Cost sharing]

- The host state is basically responsible for land acquisition, civil construction works including the tunnel, and infrastructure development. Member states make in-kind contributions for the accelerator and detectors.
- A contingency (about 10% of the total project cost) is required to deal with unforeseen events, and a common fund is required to pay for some items such as the experimental hall, which cannot be shared through in-kind contributions. The ILC Laboratory requests member states to provide in-cash contributions and manages them.
- In addition to the costs listed above, assuming that the host state will also wish to have a share not smaller than other major contributing states in the provision of technologically advanced items such as superconducting radio frequency technology, a total host state contribution of approximately 50%* seems likely.

  * It is noted in the "Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community" reported by LCB in November 2017 that in recent examples of similar international projects, the host country made the majority contribution.
- As for operational costs, three possible scenarios and their combinations are under study as a model of cost sharing:
  i) in proportion to the capital contributions of the partners;
  ii) in proportion to the capital contributions of the partners excluding the civil construction, land purchase costs, and infrastructure development;
  iii) in proportion to the number of PhD experimental scientists employed by each country and taking apart in the activities of the ILC Laboratory.

1-1-3. International collaboration group

- In the PIP, two detectors designed for the ILC, ILD (International Large Detector) and SiD (Silicon Detector), are being advanced by two international teams. Each design team is expected to evolve into an experimental collaboration when the ILC project is approved.
- The ILC Laboratory will operate the mechanism to evaluate submitted proposals and to oversee the progress of approved experiments. It is a common practice of the existing accelerator laboratories to organize relevant committees for this purpose, such as a Program Advisory Committee (PAC).
- Participation in the collaboration will be open to the entire world community, as for existing collaboration, such as those for LHC. Physicists from countries that do not participate in the construction of the accelerator may join experiments.
- ILC detector collaboration will be self-organizing and governing. The financial support of each collaboration should be sought, in principle, by the participating members of the collaboration from individual funding agencies. It is not expected that the ILC Laboratory will make direct contributions to the detector components except

for supply infrastructure that is common to both detectors and also staff to help with assembly and integration work.

1-2. Living environment and social infrastructure

The general requirements for living environment and social infrastructure around the ILC site, independent of the actual site, is discussed in the following report and in the PIP.

- Report on the Siting of the ILC Project (Siting Report) (Feb. 2014, KEK, Nomura Research Institute and Fukuyama Consultants)

An outline of the surrounding environment assumed in these two documents is described below.

1-2-1. Demographics

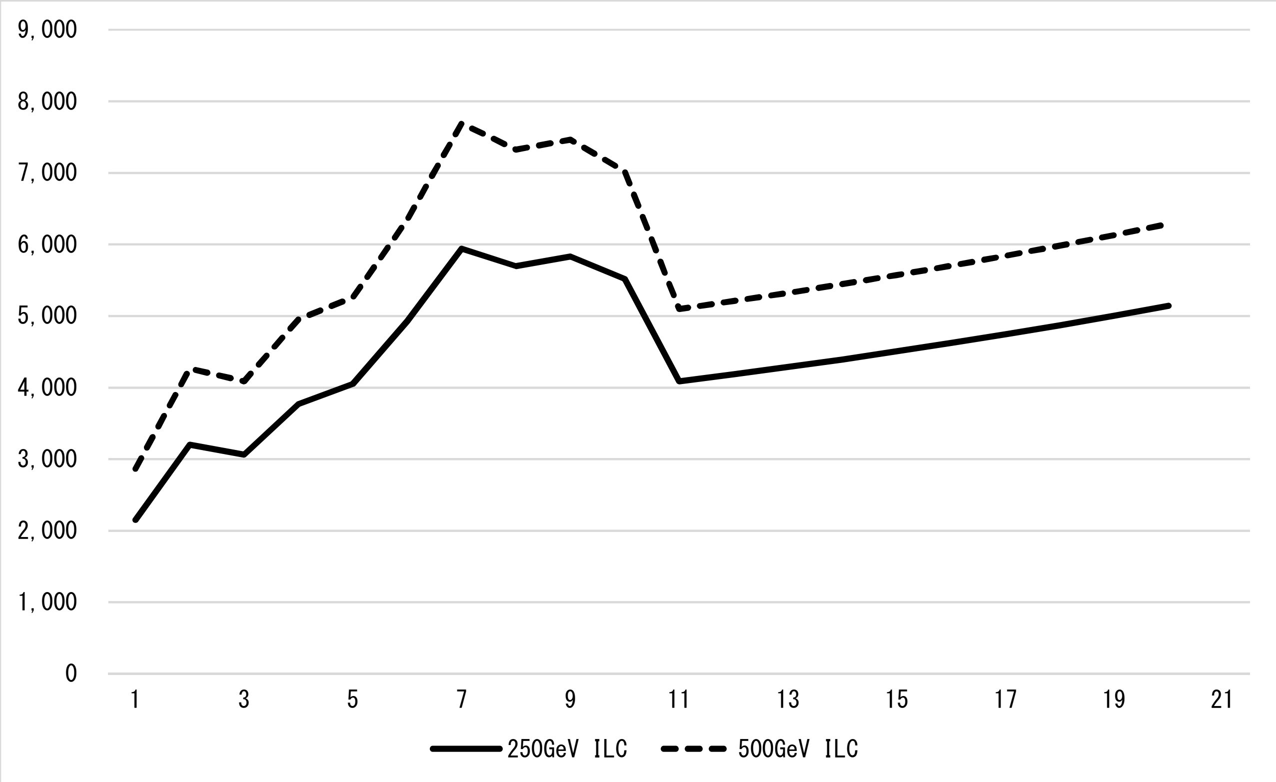
- The PIP assumes a total population of researchers, laboratory employees and their families of about 10,000, the size of a small town.
- The Siting Report estimates for different points along the timeline the ILC population living near the site -- including researchers, engineers, office staff, construction workers, maintenance staff, and their families, assuming Japan hosts the ILC Laboratory, as in the table below.

Table: Estimated population around the ILC site

	Construction period		Operation period	
	1st year	7th year	11th year	20th year
Researchers, engineers and office staff	75	1,978	1,825	2,335
Construction workers and maintenance staff	1,958	1,994	270	270
Associated family members	118	1,970	1,991	2,537
Total	2,151	5,942	4,086	5,142

Source: Revised by KEK based on Siting Report

Figure: Population changes related to the ILC project around the ILC site



Source: Revised by KEK based on Siting Report

1-2-2. Living environment and social infrastructure

- The PIP summarizes the requirements for living environment and social infrastructure as below.

  [Living environment]

  - Conventional utilities and services need to be available to the researcher community, such as job opportunities, basic amenities, housing, and recreation facilities.
  - It is also indispensable to establish a high-grade multi-lingual kindergarten and elementary schools for the children of ILC Laboratory staff.
  - For short-term visitors, immigration procedures should be simple, such as multi-entry visas, and on-site lodging, hotel and guest houses will be needed.
  - Basic security and health care infrastructure, such as fire and disaster prevention, emergency medical service, and hospitals, should be secured.

  [Social infrastructure]

  - Very high-bandwidth network connections to every country/institution participating in the ILC project is needed.

- Conventional support utilities (electrical power, industrial cooling water supplies, sanitary and waste disposal systems, and fuel resources such as oil and natural gas) should be available.
- Access routes, roads, and rail, capable of bearing loads as heavy as 70 metric tons should be available from a port to the site.

• The Siting Report lists the requirements for living environment (housing, childcare, education, medical care, health insurance, livelihood support, finance, transportation, shopping, food, culture, recreation, visas, residence status, and employment) and the requirements for social infrastructure (wide-area transportation, information networks, and supply processing infrastructure), should Japan host the ILC (Appendix 1).

• Morioka City used the Siting Report to study the construction costs for the central campus and housing for the researchers and their families, as shown in the table below.

Table: Additional costs derived by 500GeV ILC plan that go into ILC construction

	Construction Cost (billion JPY)	Remarks
ILC Central Campus Construction	60.2	Spending on the ILC Central Campus site (high-rise architecture: 31.7ha, not including the site cost) Spending on the building of facilities on the ILC Central Campus (including research administration, experiment facilities, on-site dormitory, service facilities; total floor area: 120,000m^2)
Housing for Researchers (off campus)	65.2	Spending on the building of 1,917 homes off campus
Total	125.4	

Source: Report on the Influence of the ILC Project (Influence Report)
(Mar. 2015, Nomura Research Institute and Fukuyama Consultants)

Notes;

- This estimate does not presume any particular location in Japan
- The cost of ILC Central Campus construction (60.2 billion JPY) overlaps partially with the initial cost estimate for the Central Campus construction described in the TDR. Thus this is not necessarily required in *addition* to the ILC construction cost.
- The estimated cost of housing for researchers (65.2 billion JPY) assumes all required off-campus housing is newly constructed.
- The construction cost may be reduced by the revised 250GV ILC plan. Private-sector vitality should be brought into perspective also.

2. Reviews of international research body's organization and management

Sections 2, 3 and 4 review the organizational structure and management of an international laboratory, its living environment and social infrastructure described in the previous section. They also review and summarize the implementation structure for hosting such an international laboratory in Japan in the event that the ILC is hosted in Japan.

2-1. Organization and management of pre-lab

- In the KEK-ILC Action Plan, it is assumed that the headquarters of the pre-lab is located at KEK, in the event Japan hosts the ILC. It should be noted that the timing and range of relocating resources from KEK's on-going research program to the pre-lab must be carefully determined based on discussions not only with the relevant research groups but also with the international research community. The relocation should not negatively affect on-going research programs at KEK.
- The KEK-ILC Action Plan assumes that the pre-lab consists of 200 accelerator experts, and therefore a significant number of accelerator researchers who must be newly trained. These personnel should be employed according to a well-organized plan. It is effective to train them at accelerator facilities in operation, such as the SuperKEKB (electron-positron circular collider operated by the KEK) and J-PARC (Japan Proton Accelerator Research Complex, run jointly by KEK and JAEA – Japan Atomic Energy Agency), in order to take advantage of the experience of researchers at these facilities.
- Industrial partners responsible for production also need to convene engineers and technical staff with professional knowledge and skill. They could be temporarily relocated to the pre-lab and collaborate with the researchers there for training. This would provide useful methods to supplement the human resources of the pre-lab.
- Administrative functions of the pre-lab should be reinforced to satisfy of requirements of the international organizations, in terms of, for example, multi-lingual readiness, public relations, intellectual property management, export-import operations, and technology transfer.

2-2. Organization and management of the ILC Laboratory

2-2-1. Legal basis

- It makes sense that the PIP recommends establishing and running an international treaty organization as the ILC Laboratory because the ILC is a facility that requires a long-term commitment from multi-national partners, particularly in terms of funding.
- A framework for negotiating the authority sharing among states in accordance with their responsibilities will be necessary since each country will contribute a share to the large facility and enormous assets of the ILC. A treaty-based framework will facilitate this process.

- An international treaty organization, in which participating entities are responsible for the execution of the terms of a strongly binding agreement, also deters them from withdrawing midway, leading hopefully to sustainable operation.
- On the other hand, reaching consensus on an international treaty organization may require protracted negotiations.
- An alternative international agreement other than a treaty should be devised in order to avoid an impasse that might be brought about by a participating entity due to domestic constraints. A legally binding instrument would still be effective in avoiding possible conflicts.
- The United Nations University is an example of an international treaty organization that could work should Japan host the ILC. Articles in its agreement (*Agreement regarding the Headquarters of the United Nations University*) stipulate, for example, tax exemptions, privileges for the officers and staff members, making it a useful reference for an ILC agreement.
- Another useful reference is found in the ITER Agreement (*Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project*) concerning the process and responsibility of participants up through to the end of the project as stipulated in the PIP.

2-2-2. Top management (executive board) and project management

- The PIP assumes the ILC Laboratory is to be established as a new international organization. Thus, full-time employees should be recruited to facilitate prompt decision-making and operations.
- Staff members capable of working in an international organization should be newly recruited. Difficulty relating to starting up a new research institute is recognized as one of the reasons why the Superconducting Super Collider (SSC) in the US failed. The lessons from the SSC project suggest to consider reducing the risk of project failure by its structure, for example, restructuring an existing institute.
- The top management (executive board) assumed in the PIP is reasonable which reflects experience gained in international research organizations in different research fields such as the ITER in addition to high-energy physics laboratories like CERN. Assigning internationally recognized researchers with high management skills as top managers (executive board) will be important to secure effective management.
- Project management as described in the PIP entails the central project team that serves as an engine to lead the project by, for example, managing the resources both in-cash and in-kind contributed by participating entities. The team should be reinforced by inviting high-profile talent with sufficient experience organizing production; controlling quality and reliability; and distributing the budget, as well as managing research project(s).
- In establishing an international organization, its organizational structure and personnel appointments are two sides of the same coin. In the event that Japan hosts the ILC, a

domestic leadership training program should be laid out in order to enhance Japan's presence as the host state, in addition to securing experienced international management resources*.

* Refer to *Report on Measure to Secure and Develop Human Resources for the International Linear Collider* published in July 2016 by ILC-AP.

- A good lesson on human capital development can be learned from the Atacama Large Millimeter/Submillimeter Array(ALMA). The presence of Japan has been appreciated in the ALMA thanks to Japan's commitment in every aspect of the project, including budget, personnel, security, public relations and labor management; taking risks even in difficult situations.

2-2-3. Accelerator manufacturing framework and cost sharing

- If equipment fabrication is shared among participating entities in accordance with their in-kind contributions, as assumed in the PIP, local industry could receive contracts according that country's fractional contribution. Contingency risks could thus be spread among participating entities.
- Despite the above advantage, in-kind contributions risk schedule delays and cost overruns due to the complexity of production management when considering the budget and progress in each country/region and the interfaces among components provided by other countries.
- Consequently, there remains a risk that the sharing of responsibility is not clearly defined, because overall specifications are being decided primarily by the ILC Laboratory, while the cost and delivery of in-kind contributions are being decided by each hub laboratory.
- In fact, a serious conflict broke out between the ITER Organization and participating institutes in 7 members (the European Union, Japan, the US, Russia, China, Korea, and India), concerning inter-apparatus interfaces and process control together with various other managerial issues. This conflict led to further delay and a cost overrun.
- Even when a hub laboratory cannot solve a problem alone, the project schedule should be maintained within the budget by having the ILC Laboratory coordinate among the hub laboratories, and by having the hub laboratories manufacture at its discretion within the range of its delegated authority. For this to work out well, clarifying the rules to modify specifications and the authority of the ILC Laboratory and each individual hub laboratory will be essential.
- The PIP proposes that both the contingency and the common fund should be provided by in-cash contribution. Lessons learned from other international projects listed below include the importance of setting the right size of contingency fund to deal with various unforeseen circumstances even for problems related to in-kind contributions.

[CERN]

This institute, operated by in-cash contribution from member states, is able to take prompt action against risk and to reduce cost by implementing a centralized budget. Making available a long-range budget outlook enables the levelling out of budgetary changes during construction and coping with unforeseen circumstances.

[ITER]

In 2015, a reserve fund, under the control of the director-general, was created to cope with design changes and unforeseen equipment procurement. This fund enabled a more streamlined management and timely budget allocation, for example, to control inter-equipment interfaces.

[ALMA]

The lack of contingency in the Japanese budget is seen as a problem. The contingency should be included in the budget plan and should be used at the discretion of management.

2-2-4. International cost sharing

- The PIP assumes the host state's financial contribution* to ILC construction and management to be no greater than approximately 50%†, with the remainder to be shared among the member states. The operational budget of the accelerator is also to be shared among participating entities; several cost sharing methods are being discussed. As an international organization financially supported by the participating entities, a balanced management system is indispensable to avoid excessively centralized power accruing to the host state and to guarantee an appropriate degree of authority for each member state.

  * Not including the costs to improve living environment and social infrastructure

  † It is noted in the "Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community" reported by LCB in November 2017 that in recent examples of similar international projects, the host country made the majority contribution.
- International cost sharing differs for different projects. Examples presented at the organization and management working group meetings are shown below.

[ITER]

The host "premium" increased during the course of bidding for the site. Later negotiations, however, readjusted the contribution to 45.46% for the host and 9.09% each for the remaining partners (Japan, the US, Russia, China, Korea, and India), securing democratic decision making and preventing the host from securing a controlling majority.

[CERN]

European countries established it in 1957 in response to the rapid expansion of a scientific project and to the perceived need to compete with the US and the Soviet Union. The financial contribution of a member state was originally based on its GDP while the system of sharing* over the past three years is based on its Net National Income (NNI).

* Top three countries in financial contribution (2015) were: Germany (20.5%); France – the host country (15.1%); and the UK (14.3%). Switzerland, another host country contributed 3.9%.

[ALMA]

While started with the assumption that the total cost would be divided equally among Japan, North America, and ESO (European Southern Observatory), during the course of project approval and budget negotiations in each country, the final fractional contribution resulted in 25% from Japan and 37.5% each from North America and ESO.

- International cost sharing will be negotiated among participating governments. Agreement will be reached only after the project is approved by a science council or its equivalent in each country and progress towards securing the budget in each country, made by each government.
- Considering the possibility that the ILC Laboratory hosted by Japan may be regarded as an Asian international research center complementary to CERN in Europe, the project should be open to Asian partners that could join and cooperate with proper financial contributions.

2-3. Organization and management of detector construction and international experiments

- Two experiments, the ILD and the SiD as assumed in the PIP, allow scientific cross-checks, but the costs of building detectors and the experimental hall will rise. The need for two experiments should be carefully investigated.
- As in the case of previous experiments at accelerator facilities, an experiment at the ILC should be open to any institutions in any country/region. Democratic administration should be secured through a management body of an appropriate size comprised of elected members with limited terms. A high-level decision-making body should oversee the executive management.
- Some may argue that cost-effective participation with less contribution is possible. In the event that Japan hosts the ILC, it will be important to demonstrate clearly the rationale, appropriateness and merits of hosting the ILC.
- Strategic management of the ILC experiment is required to ensure that each country has a balanced share of responsibility for detector construction; of group management

that requires significant budget and human resources; and of responsibility for data analysis that is more attractive academically.

3. Reviews of living environment and social infrastructure

3-1. Demographics

- The PIP assumes a total population of researchers, laboratory employees, and their families of about 10,000, the size of a small town. The Siting Report estimates an ILC-related population around the site of 6,000 in the construction peak 7th year; 4,100 in the 11th year after the start of operations; and 5,100 in the 20th year.
- However, the above estimates should be reexamined for the following reasons. Firstly, the population around the site may diminish after the construction period as collaborators are able to carry out data analysis at their home institutions thanks to high-speed internet connection achieved with currently available technology.
- Secondly, it should be noted that CERN, on which the above estimation is based, is located in the vicinity of Geneva, an international city.

3-2. Requirements for living environment and social infrastructure

- With the above caveats, the population estimated in the PIP and the Siting Report should be readjusted for designing the living environment and social infrastructure around the ILC site based on more realistic data for the case that Japan hosts the ILC.
- Requirements for living environment and social infrastructure include housing, childcare, education, medical care, life support, finance, transportation, shopping, food, culture, recreation, visa, residence status, job opportunity for family members, and participation in community activities. Support from local governments around the ILC site will be indispensable to provide public facilities and services to satisfy some parts of the requirements.
- Development of local infrastructure is a significant investment, and the cost sharing should be sorted out between the ILC Laboratory and relevant organizations such as the central/local governments, with the possibility of cost sharing between the host state and member states.
- Unlike the case of ITER, in which the cost of local infrastructure was covered primarily by the host state* as a result of international competition in project invitation, a more balanced sharing would be better for the ILC for which there is no such international competition.

  * Responsibility of the host state, France, is defined in the ITER Agreement Annex. Within this framework local governments agree to share the cost for ITER infrastructure development with 467 million euro over 10 years.
- As Japan suffers from frequent natural disasters such as earthquakes, safety will be essential for the ILC to coexist with local governments. It will be important to build a

good relationship with local governments, considering the fact that the ILC Laboratory will handle radioactivity.

4. Study of a plan to set up an international research institute in Japan

4-1. Participation of Japanese universities in ILC experiments collaboration

- Make good use of the experience gained in the management of the Belle II experiment, which is currently under way as a joint international project hosted by Japan.
- It is difficult for a research group at a university to make a visible contribution to a huge international accelerator experiment. Devise a strategy to strengthen the presence of Japanese universities if the ILC Laboratory is hosted by Japan.
- Invest available resources in a focused manner, by establishing a national consortium for the detector development and data analysis. This scheme will be effective in increasing the presence of Japanese universities. It will also encourage talented foreign scientists working at the ILC Laboratory to visit and collaborate with university teams, thereby helping domestic universities internationalize.
- Establish a training course on special topics, such as accelerators, cutting-edge semiconductor detector technology, electronics, and computing, with the cooperation between the ILC Laboratory and universities. The courses would be for young researchers who will be able to work in an international environment.
- Provide a training opportunity for technical and office staff to improve multilingual communication skills and their ability to provide technical and administrative support to researchers.

4-2. Relationship between KEK and the ILC Laboratory

- In the event that Japan hosts the ILC, KEK is expected to conduct research programs in disciplines different from those at the ILC Laboratory. A model can be found in Europe, where particle physics research is integrated into CERN, while other national laboratories, such as DESY (Deutsches Electronen-Synchrotron) in Germany and PSI (Paul Scherrer Institute) in Switzerland, constructed accelerators for purposes different from the one at CERN, such as creating a light source that includes free electron lasers and a high-intensity proton accelerator.
- Even after the ILC is built in Japan, the national accelerator laboratory, namely KEK, needs to be maintained, taking maintenance and development of expertise and technology into account. Financial constraints, however will make it difficult to maintain the funding level as is, and the programs will be subjected to close scrutiny by the relevant communities.
- A strategy taken by DESY provides a good model for the future of KEK in the event Japan hosts the ILC. Among the accelerator laboratories in the world that shifted their research focus from particle physics to photon science, DESY maintains an active group of experimental particle physics researchers and plays a leading role in the high-energy

physics programs at CERN and KEK, although photon science is DESY's current major research program.

- When DESY terminated its accelerator operations for high-energy physics at almost the same time as CERN began the operation of the LHC, many researchers at DESY joined the LHC experiments while keeping their affiliation to DESY. In a similar way, high energy physicists at KEK could join the ILC experiments while keeping their KEK positions.
- It is important for the ILC Laboratory to have a strong central team with clearly defined authority. KEK is expected to support early establishment of such a central team as the main laboratory for the hosting country.
- It will take time before the ILC central team can seize the initiative, particularly in technology. By assigning leaders capable of leading an international team, with the support of KEK on various issues, the leadership in accelerator construction will be gradually transferred to the central project team.

4-3. The future of high-energy physics in Japan

- At the building a new accelerator, the available knowledge and technology together with future progress will need to be considered. In Europe, the European Committee for Future Accelerators(ECFA), organized by the European particle physics researchers' community, led discussions on the type of accelerator, the available technology and an appropriate host institute. The host institute in each country submitted a proposal; then the science council in each country coordinated various disciplines; and finally the government decided go or no-go.
- The Japanese high energy physics community is currently conducting diverse research programs and has proposed a huge project, ILC, as a major future project. The community must establish a consensus on a future research strategy by limiting the number of projects to implement the ILC project.
- A model can be found again in Europe. European laboratories working on fusion science concentrate their efforts on the completion of ITER procurements, support the ITER project and related R&D for prototyping, following the roadmap laid out by EUROfusion*, a European consortium that coordinates fusion research in Europe.

  * A consortium composed of 30 research institutes and organizations from 26 countries in the EU, Switzerland, and Ukraine. EUROfusion manages European nuclear fusion research other than ITER procurement.

4-4. Industrial participation including Japanese corporations

4-4-1. Hub laboratories and industry

- The PIP assumes a promising model of production that entails mass production of superconducting cavities and cryo-modules at regional hub laboratories in a short period of time. This framework enables corporations to conduct R&D without capital investment. Access to the technical expertise benefits industry.

- Corporations without assembly facilities can justify new capital investment by noting that experience gained by the ILC project will lead to future spin-off business. A participating company, for example, is expected to have access to the assembly facilities to meet future demand.
- Application of superconducting cavity technology is important, although this is not so clear at present. Spin-offs and technology transfer should be promoted by collaborating with industry, just as CERN supports knowledge transfer by establishing a dedicated support group (CERN Knowledge Transfer Group).
- To reduce the costs of ILC construction, it will be important that hub laboratories provide technical support to the industry and that they share information among themselves. In the long history of the development of high-energy accelerators and superconductor technology, researchers at academic institutions and industrial engineers have shared their experience in joint R&D, even their experience of unsuccessful results. The top management of the ILC Laboratory should also make use of this collaborative practice.

4-4-2. International tender

- Procurement for the ILC project is expected to comply with the WTO Agreement on Government Procurement. The contract therefore may not be won by a company that has already established a strong partnership with a hub laboratory. It is important to devise a procurement system and a procedure to quickly build up partnerships with contractors that have little experience in collaborating with a hub laboratory.
- In Japan and Europe, research institutes and industries often establish partnerships for the production of equipment, while in the US, it is usually manufactured in an in-house workshop. These differences in industrial culture should be respected as long as performance meets the specifications.
- A long and strong academia-industry partnership is one advantage to the Japanese way of manufacturing. Both parties should make an effort to maintain this good practice while ensuring compliance with international rules of procurement.

4-4-3. Lessons learned from previous accelerator projects

- It has been pointed out that the cancellation of the SSC originated from the alienation of the management of a production team in industry from the management of a design team at the institute. It is essential to establish a well-defined chain of command under the leadership of a scientist extraordinarily capable of management.
- A distinctive character common to most Japanese research institutions is a lack of engineer positions. Obviously a team comprised only of scientists will be unable to manage an international project as large as the ILC. Therefore, a strong management team should be established by inviting talent rich in experience on big international projects from both academia and industry.

- CERN, as a powerful central institute, has dealt with various problems arising at the LHC in cooperation with other world-leading institutes. The ILC project should learn from their experience.
- As the PIP was worked out only by scientists, some industrial angles are missing. Further study is needed to elaborate the plan of ILC management in cooperation with industry.

Table: Desirable features in the living environments at / around the ILC lab, as noted by members of the research community.

Subject field	Desirable features / characteristics		Comments / Solution examples
Housing	Residential area	Suitability for daily lives and lifestyles of members / visitors from overseas	- Residential areas should be commutable within 30 – 40 minutes by private cars and/or public transportations <Ref: the reality of needs for foreign researchers in the similar research institute>
	Short-term housing (<90 days) stays	Fulfilment of typical expectations of members / visitors from overseas	- On-site or near-site housing (guesthouse, dormitory and hotel etc.) - Basic amenities (complete set of a bedroom with air conditioning, private shower and bathroom) at affordable fees.
		Assistance for reservation and stay	- User-friendly reservation system - Basic daily services (cleaning, meals etc.)
	Long-term housing (>90 days) stays	Fulfilment of typical expectations of members / visitors from overseas	- Off-site housing in the residential area for members / visitors with their families - On-site or near-site housing <On-campus residence is likely to be preferred before the members/visitors and their families familiarize themselves with life in Japan > - Reasonably spacious living and bedrooms, adequate bathrooms etc. - Furnished housing as an option
		Housing service	- Assistance for housing search and leases. <Posting of information for good properties. Assistance during lease negotiations etc.> - Elimination of restrictive practice in housing contract, if any, which causes difficulties for visitors/members from overseas. <Prepayment 6 months deposits, "Japanese-only" etc.>
Child care / Education	Multi-lingual childcare	Day-care services with multi-lingual, multi-cultural support	- New on-site or near-site day-care services. - Multi-lingual, multi-cultural assistance at existing day-care services in the vicinity - Childcare workers with multi-lingual capabilities >
	Multi-lingual education service	International schools	- New international schools <international curricula, multi-lingual classes> - Increased capacity for existing international schools - Possible financial aids for expenses < Financial aids from the laboratory and/or from the host nation/region >
		Multi-lingual support at existing schools	- Care and support at existing schools for students from overseas. <Multi-lingual teachers, multi-lingual support personnel, multi-lingual teaching materials >

Medical care/ health insurance	Medical care services	Multi-lingual and multi-cultural assistance at medical facilities	- Multi-lingual assistance at pharmacies <Translation of prescriptions descriptions, staff with multi-lingual communication capabilities> - Multi-lingual and multi-cultural support at hospitals and clinics <staff with multi-lingual communication capabilities>
		Multi-lingual and multi-cultural assistance in emergency medical care	- Multi-lingual support in emergency calls and emergency transport systems. - Multi-lingual support at emergency medical institutions.
		Assistance for medical care service users	- Interpreters who are specialized in medical issues with multi-lingual capabilities - Multi-lingual brochures for users of medical facilities
	Health insurance	Coverage of visitors / members from overseas	- Medical insurance for long-term and short-term visitors / members from overseas
General service	General service related to daily lives of visitors / members from overseas	Effective service system	- Offices dedicated to provide visitors / members with daily-life related services (e.g. international support office. Possibly, a specialized organization to support foreign life support)<To be set up within or near the lab possibly jointly with the host area> - Services on subjects such as: relocation, major purchases (e.g. automobiles), school attendance, visits to clinics or hospitals, administrative procedures, guidebooks on life in Japan, etc.
		Multi-lingual capabilities at municipal offices	- One-stop service desk at municipal offices for visitors / members from overseas - Attendance of support personnel with multi-lingual capabilities - Various information brochures prepared in multiple languages - Guidebooks in multiple languages on emergency/disaster management
Banking and credit services	Convenience and usability for visitors / members from overseas	Banking service	- Caching withdrawals using overseas credit cards at ATMs <ATMs with multi-lingual support for overseas credit cards, with possible off-hours support> - Assistance for account opening processes by lab members from overseas.
		Credit cards	- Improved procedure and processing speed for credit card acquisition by lab members from overseas <Speedier and less cumbersome processing >
Transportation	Easy-to-use transportation	Public transport services	- Commuting bus. On-campus bus service. On-demand bus service - Extension of public transportation routes or introduction of new ones, if needed, to incorporate stops at the institute and major residential areas - Accommodation of specific needs by lab members, including late night service and multi-lingual assistance

		Assistance for acquisition of private transportation measures (e.g. automobiles)	- Assistance for acquisition of driver's licenses by members from overseas <Areas of improvement include: driver's schools, driver's exams, license renewal, etc > - Assistance during purchasing of automobiles and related administrative procedures < Garage certificate, credit, insurance, emergency response, etc. > - On-site parking space at the lab - Carpool and ride sharing for visitors / members and their families
Shopping/food	Multi-lingual, multi-cultural services	Daily products sales service with multi-lingual, multi-cultural considerations	- Market stores in residential areas to offer multi-lingual, multi-cultural support < Multi-lingual displays, multi-cultural products > - On-site kiosks to offer multi-lingual, multi-cultural support
		Food service with multi-lingual, multi-cultural considerations	- Restaurants in residential areas to offer multi-lingual, multi-cultural services < Multi-lingual displays, multi-cultural products and cuisines> - Adequate considerations for customers with dietary restrictions
Culture / recreation	Accessibility to Japanese other cultural experiences	Japanese language and culture	- Japanese language courses and cultural courses for visitors / members from overseas < Programs jointly provided by the insititute and local communities> - Daily life related information that is available via institution web sites and/or SNS <Local community exchange programs, events, markets, garage sales, sport clubs etc.>
		Non-Japanese language and culture	- Accessibility to non-Japanese / overseas media (newspaper, magazine etc.) - Accessibility to facility for diverse religions and non-Japanese cultural activities - Internet connectivity <Fast processing of applications by new household >
	Accessibility to sporting and recreational facility	Provision of suitable facility services	- Accessibility to sporting facilities in residential area's neighborhood < Gyms, swimming pools, stadiums etc.> - Accessibility to recreational facilities in residential area's neighborhood < Gardens and parks for refreshment and amusement >
Visas	Assistance for visa application	Assistance for application of resident status, resident cards	- Assistance for application of resident status and registration for institute members and their families from overseas - Timely processing of applications for visa and resident status
Opportunities for jobs and social activities	Opportunities for jobs and social activities for spouses and family members from overseas	Social activities	- Opportunities to be offered to staff, their spouses and family members from overseas to participate in local social activities and events
		Employment	- Job opportunities for spouses and family members from overseas - Accessibility to information on job opportunities

Table: Desirable features in the social infrastructure at / around the ILC lab, as noted by members of the research community.

Subject field	Desirable features / characteristics		Comments / Solution examples
Transportation	Existence of a major international / domestic airport	Existence of a hub airport.	- Existence of a major hub airport on its own in the immediate neighborhood, or - Strong connectivity to a major hub airport
	Accessibility to an international / domestic airport	Public transportation measures to easily and quickly access an international / domestic airport	- Direct access to an airport by public transportation measures < Direct bus services to an airport or to train (shinkansen) stations which allow direct access to an airport >
	Existence of a major port facility	Existence of a major port facility suitable for handling international cargos	- Having an international container terminal, securing certain container international routes and flights - In addition to handling equipment for large-scale equipment, development large warehouses and CIQ systems
		Availability of ground access to a major port facility	- Availability of ground access routes for special vehicles to carry extremely large and heavy freight from a major port facility <New routes to prepare, if needed > - Availability of facility and routes for accepting and transporting international shipping containers to / from the ILC. < Capability to handle 45ft containers >
	Proximity to wide-area highway network	Availability of ground access routes to wide-area highway network and expressway interchanges	- Availability of ground access routes to wide-area highway network <new access routes, if needed, from the lab area> - Availability of ground access routes to expressway interchanges. <If needed, new routes to existing interchanges or new interchanges >
	Proximity to wide area railway network	Availability of public transportation means to railway stations	- Accessibility to wide-area public transportation systems < Public bus services to railway / Shinkansen stations, as found necessary depending on the demand and regional plans >
		Availability of railway hub associated with a wide-area transportation terminal function	- Availability of railway hub station associated with a wide-area transportation hub terminal function < Wide-area hub terminal with adequate multi-lingual support> - Availability of sufficient transportation capacity <Support commutes by local residents and the ILC users>

IT infrastructure	Broadband network connectivity	Broadband network connectivity within the lab area and with the global research communities	- Connection with academic information network(SINET4: Science Information NETwork)<Connection for SINET node(Connection base with network> - Tera-bit class core optical fiber network <Connected sites include: the ILC main campus, satellite campuses, international IX, international communication cable hubs>
		Introduction of international IX(internet Exchange)	- Introduction of International IX to become a node with direct links to the world Internet from the lab ※IX stands for "Internet eXchange", meaning a connection point on the Internet that interconnects networks including multiple ISPs. An international IX in Japan is a connecting point both domestic and overseas internet.
	Mobile connectivity	Introduction of mobile phone connectivity in accordance with international standard	- Introduction of GSM(Global System for Mobile Communications) area - Introduction of next-generation base station
Utility infrastructure	Electric power	Electric power to sustain ILC operation (> 200MW)	- Redundant power receiving facility to manage emergency (Substation (surface) and sub substations (underground)). - Connection with power grid <cooperation with the local electric company under agreement>
	Water	Supply of water and handling of waste water for ILC operation	- Use of drain water from the tunnel <Introduction of reservoir>
		Cooling water system of ILC facility	
		On-site water-related facilities	- Life water supply to be coordinated with municipalities - Waste water disposal to be handled at community plant with possible expansion
	Waste disposal	Excavated soil and stones during construction	- Availability of stockyards and crushing yards. Reuse of excavated soil and crushed stones. - Wastes during construction to be handled primarily at existing local disposal facilities.
		General waste from campus	- To be handled by existing local facilities < Planning required under coordination by municipalities>

Source: Siting Report

Supporting Documents

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（July, 2018）

International Linear Collider (ILC) Advisory Panel
Elementary Particle Physics and Nuclear Physics Working Group membership

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(July, 2018)

International Linear Collider (ILC) Advisory Panel
Technical Design Report(TDR) Validation Working Group membership

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Takashi KATO	Managing Director, Nippon Advanced Technology Co., Ltd.
Osamu KAMIGAITO	Director of Accelerator Group, RIKEN Nishina Center for Accelerator-Based Science
Michio KITAMURA	Professor, Graduate School of International Media, Communication and Tourism Studies, Hokkaido University
Noritaka KUMAGAI	Honorary Fellow, Japan Synchrotron Radiation Research Institute
Haruyo KOISO	Professor, Accelerator Laboratory, KEK
Tadashi KOSEKI	Deputy Director of J-PARC Center, KEK
Shigemi SASAKI	Research Professor, ShanghaiTech University Professor Emeritus, Hiroshima University
Hitoshi TANAKA	Deputy Director of SPring-8 Center, RIKEN
Hiroshi CHIKAHISA	Director, CTO, GeoSystem Institute Inc.
Fujio NAITO	Professor, Accelerator Laboratory, KEK
Koji NODA	Managing Director, National Institute of Radiological Sciences
* Hideaki YOKOMIZO	President of Comprehensive Research Organization for Science and Society

*：Chair

(July, 2018)

International Linear Collider (ILC) Advisory Panel
Human Resource Securing and Developing Working Group membership

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Naoaki IKEDA	General Manager, Electricity & Control Systems Engineering Department, Machinery System Division, Mitsubishi Heavy Industries Mechatronics Systems, Ltd
Haruo OHKUMA	Specially Appointed Nonregular Employee, Japan Synchrotron Radiation Research Institute
Hiromi OKAMOTO	Professor, Graduate School of Advanced Sciences of Matter, Hiroshima University
Yukio KUMATA	Vice President, Sumitomo Heavy Industries, Ltd
Tadashi KOSEKI	Deputy Director of J-PARC Center, KEK
* Takashi NAKANO	Director of Research Center for Nuclear Physics, Osaka University
Tsuyoshi NAKAYA	Professor, Graduate School of Science, Kyoto University
Akira YAMAMOTO	Professor Emeritus, Researcher, KEK
Hideaki YOKOMIZO	Director of Research Center for Neutron Science and Technology, Comprehensive Research Organization for Science and Society
Hiromi YOKOYAMA	Associate Professor, Graduate School of Science, The University of Tokyo

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(June, 2016)

International Linear Collider (ILC) Advisory Panel
Organization and Management Working Group membership

Toru IIJIMA	Director of Center for Experimental Studies, Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University
Tomohiro IJICHI	Dean, Faculty of Innovation Studies, Seijo University
Atsuko ICHIKAWA	Associate Professor, Graduate School of Science, Kyoto University
Kiyotomo KAWAGOE	Director of Research Center for Advanced Particle Physics, Kyushu University
Michio KITAMURA	Professor, Graduate School of International Media, Communication and Tourism Studies, Hokkaido University
Kiyokazu SATO	Senior Fellow, Keihin Product Operations, Toshiba Co.
Hideyuki TAKATSU	Deputy Director of Kobe Center, Research Organization for Information Science and Technology Former Chairman of the ITER Council
Hitoshi TANAKA	Deputy Director of SPring-8 Center, RIKEN
Katsuo TOKUSHUKU	Director of Institute of Particle and Nuclear Studies, KEK
Takashi NAKANO	Director of Research Center for Nuclear Physics, Osaka University
Shoji NAGAMIYA	Science Advisor, RIKEN / Professor Emeritus, KEK
* Shoken MIYAMA	Specially Appointed Professor, Office of the President, Hiroshima University Professor Emeritus, National Astronomical Observatory of Japan, National Institutes of Natural Sciences
Akira YAMAMOTO	Researcher, KEK / Visiting Professor, CERN
Hitoshi YAMAMOTO	Professor, Graduate School of Science, Tohoku University
Hiromi YOKOYAMA	Professor, Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), UTokyo Institutes for Advanced Study (UTIAS), The University of Tokyo

* : Chair

(June, 2017)

ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory

The discovery of a Higgs boson in 2012 at the Large Hadron Collider (LHC) at CERN is one of the most significant recent breakthroughs in science and marks a major step forward in fundamental physics. Precision studies of the Higgs boson will further deepen our understanding of the most fundamental laws of matter and its interactions.

The International Linear Collider (ILC) operating at 250 GeV center-of-mass energy will provide excellent science from precision studies of the Higgs boson. Therefore, ICFA considers the ILC a key science project complementary to the LHC and its upgrade.

ICFA welcomes the efforts by the Linear Collider Collaboration on cost reductions for the ILC, which indicate that up to 40% cost reduction relative to the 2013 Technical Design Report (500 GeV ILC) is possible for a 250 GeV collider.

ICFA emphasizes the extendibility of the ILC to higher energies and notes that there is large discovery potential with important additional measurements accessible at energies beyond 250 GeV.

ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly encourages Japan to realize the ILC in a timely fashion as a Higgs boson factory with a center-of-mass energy of 250 GeV as an international project[1], led by Japanese initiative.

1 In the LCB report the European XFEL and FAIR are mentioned as recent examples for international projects.

Ottawa, November 2017

Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community

– Short Summary –
Linear Collider Board
8 November 2017, Rev 1

Physics studies by the Linear Collider Collaboration Physics and Detector Group[1], and the Japanese Association of High Energy Physicists (JAHEP) [2] show a compelling physics case for constructing an ILC at 250 GeV centre of mass energy as a Higgs factory. The cost of such a machine is estimated to be lower by up to 40% compared to the originally proposed ILC at 500 GeV[3]. The acceleration technology of the ILC is now well established thanks to the experience gained from the successful construction of the European XFEL in Hamburg. One of the unique features of a linear collider is the capability to increase the operating energy by improving the acceleration technology and/or extending the tunnel length. For these reasons, the Linear Collider Board strongly supports the JAHEP proposal[4] to construct the ILC at 250 GeV in Japan and encourages the Japanese government to give the proposal serious consideration for a timely decision.

In recent examples of similar international projects[1], the host country made the majority contribution. A natural expectation would be that the cost for the civil construction and other infrastructure is the responsibility of the host country, while the accelerator construction should be shared appropriately. A clear expression of interest to host the machine under these principles would enable Japan to start negotiations with international partners. It would also allow members of the international community to initiate meaningful discussions with their own governments on possible contributions.

1 Recent examples in the field close to the ILC are European XFEL and FAIR in Germany.

References

[1] K. Fujii et. al. (Linear Collider Collaboration), "Physics Case for the 250 GeV Stage of the International Linear Collider", DESY-17-155 / KEK Preprint 2017-31 / LAL 17-059 / SLAC-PUB-17161, arXiv:1710.07621 [hep-ex].

[2] S. Asai et al, "Report by the Committee on the Scientific Case of the ILC Operating at 250 GeV as a Higgs Factory", arXiv:1710.08639 [hep-ex].

[3] L. Evans and S. Michizono (Edit.) (Linear Collider Collaboration), "The International Linear Collider Machine Staging Report 2017, Addendum to the International Linear Collider Technical Desgn Report published in 2013", DESY 17-180, CERN, KEK Report 2017-3, arXiv:1711.00568 [hep-ex].

[4] JAHEP, "Scientific Significance of ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2", http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf.

16 July 2018

Reply from the Linear Collider Board to the MEXT Particle and Nuclear Physics Working Group

(Translation from the document in Japanese submitted on 16 May 2018)

In its meeting held in November 2017 in Ottawa, the Linear Collider Board (LCB) described the two accelerator based research facilities, European X-ray Free Electron Laser (European XFEL) and Facility for Anti-proton and Ion Research (FAIR), to be relevant for the current ILC discussion in the following two aspects: For both cases, the host country, Germany,

1. carried a considerable fraction of the cost[1], and
2. declared first their intention to host the facility[2] with a significant contribution and then took initiative to form an international collaboration and to play a leading role in the project realisation.

According to the LCB opinion, the host county needs to take a leadership in forming an international collaboration in order to achieve timely construction of the ILC project at the present moment. Indicating the intention of making an appropriate contribution as a host country is highly desirable to start such process.

[1] The LCB understands, as pointed out by the ILC Project Implementation Planning (PIP) that the actual sharing of the cost and responsibilities, and organisation for construction and operation of the ILC are to be decided by the negotiation among the governments of participating countries. A cost sharing model referred by the LCB in the November statement, namely "the civil engineering and infrastructure being under the responsibility of the host country while the accelerator cost being shared appropriately among all the participating countries", was introduced as an example since this scheme had already been discussed by the LCB in Valencia in July 2014 and well understood by the community.

[2] One of the four important items in the European Strategy for Particle Physics adopted by the CERN Council in May 2013 is about the ILC and reads as "Europe looks forward to a proposal from Japan to discuss a possible participation." The expectation towards the host country as it appears in the LCB statement is derived from there.

European X-Ray Free-Electron Laser

■ Synopsis

An X-ray free-electron laser facility, which is instrumental in the study of atoms, molecules and cells, located in a suburb of Hamburg, Germany. It generates high-intensity coherent X-rays with wavelengths as low as 0.05 nanometer from electron beams with an energy of 17.5 GeV on the principle of free-electron laser.

■ Construction period

Construction started in 2009

Commissioning started in 2016

User operation started in Sept. 2017

(*1) 2005 price level
(*2) 1 Euro = 136.89 Yen
(An average published by Bank of Japan in 2005)
(*3) 1 Euro = 133 Yen
(An exchange rate published by Japanese Minister of Finance in Nov. 2017)

■ Construction Cost

1.22 billion Euro (*1) (ca. 167 billion Yen(*2))

Cost sharing : Germany(58%), Russia(27%), Others(1~3% ea)

(At the start of the project, Germany contributed ca. 54% of 1,082 billion Euro, the maximum agreed cost)

■ Operation Cost

117 million Euro (ca. 15.6 million Yen(*3))

Cost sharing:

-Before user operation:
same as the sharing ratio of construction cost

-User operation phase:
50% of the total is shared following the same rule as the construction cost. The remaining 50% is shared by participating countries in proportion to their utilization

Linac modules

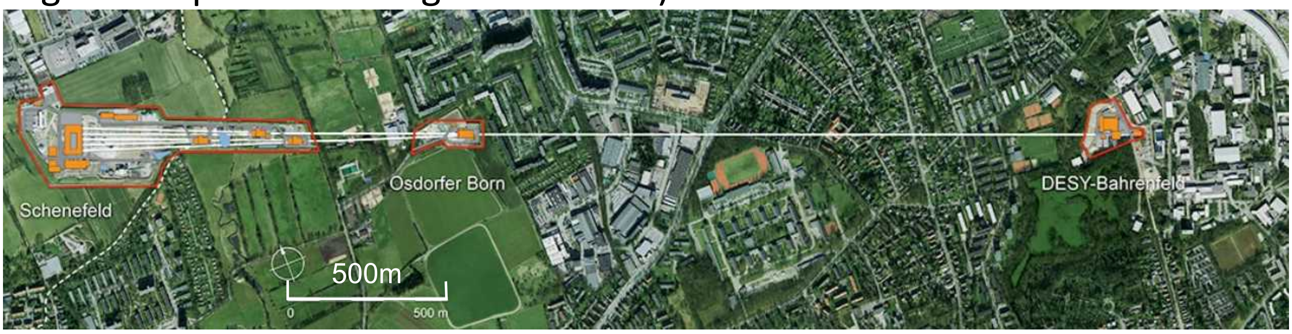
■ Participating countries (12 countries)

Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, Switzerland and United Kingdom

■ Size of the facility

Length of linac tunnel 3.4km

(Length of superconducting linac 1.7km)



Aerial view

(Summarized by High Energy Accelerator Research Organization, KEK)

Facility for Antiproton and Ion Research

■ Synopsis

A heavy-ion accelerator, which accelerates heavy ions up to uranium, under construction at a heavy-ion laboratory (GSI) in Darmstadt, Germany. By using the heavy-ion beams, various studies are being planned: high-density hadron materials, unstable nuclei and astro-nuclear physics, plasma physics with various ion-beams, medical applications such as cancer therapy, and hadron physics with antiproton beams.

■ Construction period

Started in 2017

Expected completion in 2025

(*1) 2005 price level
(*2) 1 Euro = 136.89 Yen
(An average published by Bank of Japan in 2005)
(*3) 1 Euro = 133 Yen
(An exchange rate published by Japanese Minister of Finance in Nov. 2017)

■ Construction cost

1.262 billion Euro(*1)(ca 173 billion Yen(*2))

Cost sharing: Germany(69%), Russia(17%), Others(0.5~3.5%)

(At the start of the project, Germany contributed 69% of 1,027 billion Euro.)

■ Operation cost

118 million Euro(*1)(15.7 billion Yen(*3))

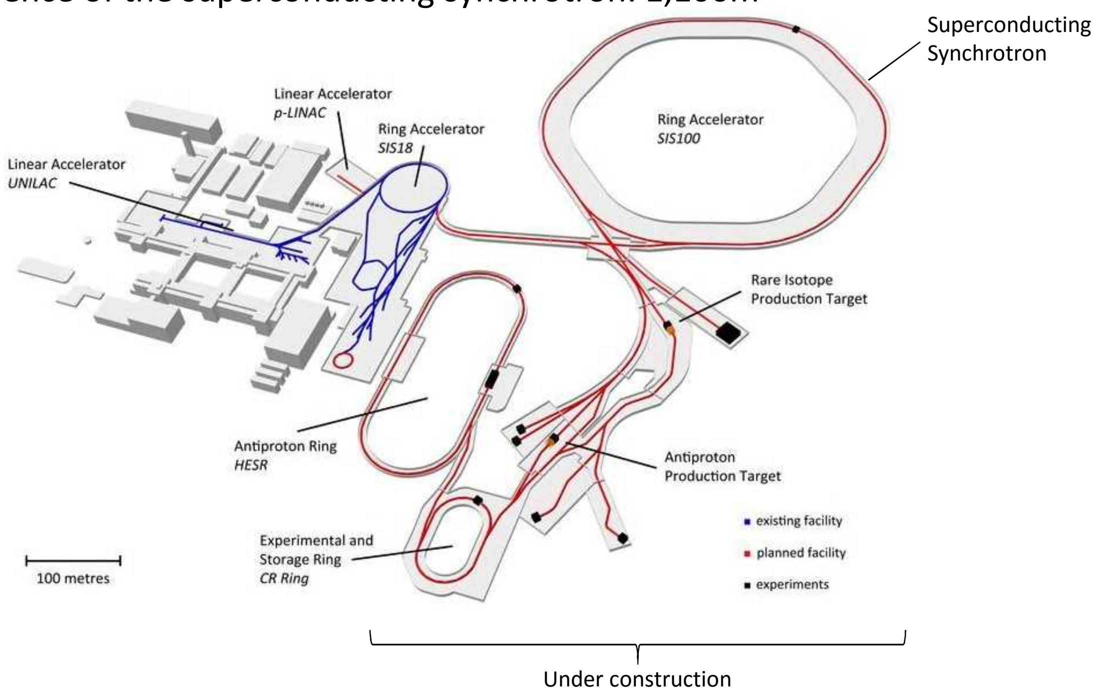
Operation cost is shared among the stakeholders of the FAIR GmbH and the sharing scheme will be decided at a FAIR Council meeting slated to take place within 3 yeas from the start of construction.

■ Participating countries (9 countries)

Germany, Finland, France, India, Poland, Romania, Russia, Sweden, Slovenia and United Kingdom(*)   (*)United Kingdom is currently associate member country

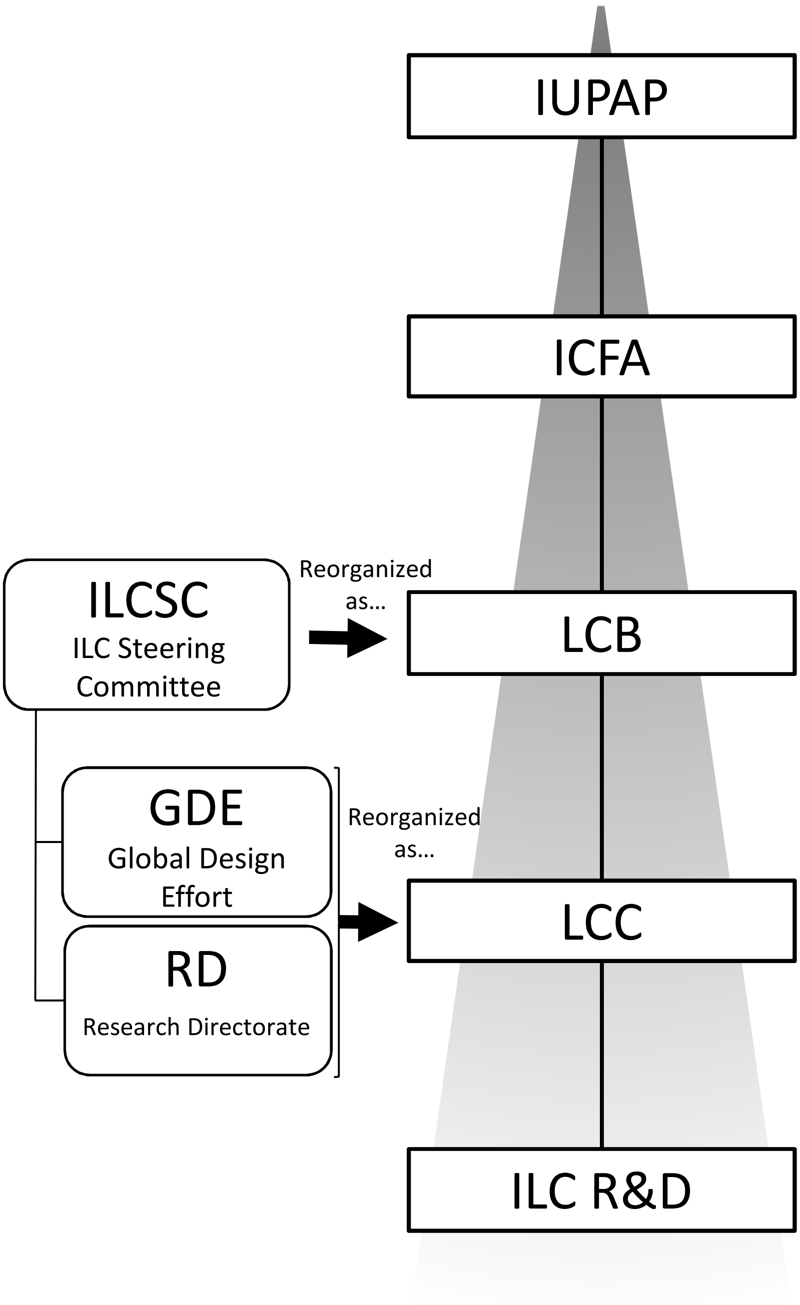
■ Size of the facility

Circumference of the superconducting synchrotron: 1,100m



(Summarized by High Energy Accelerator Research Organization, KEK)

International Organizations of ILC Researchers



The International Union of Pure and Applied Physics
Federation of physics societies in different countries intended for advancement of physics and international cooperation

International Committee for Future Accelerators
Considers future accelerator projects as a sub-committee of IUPAP

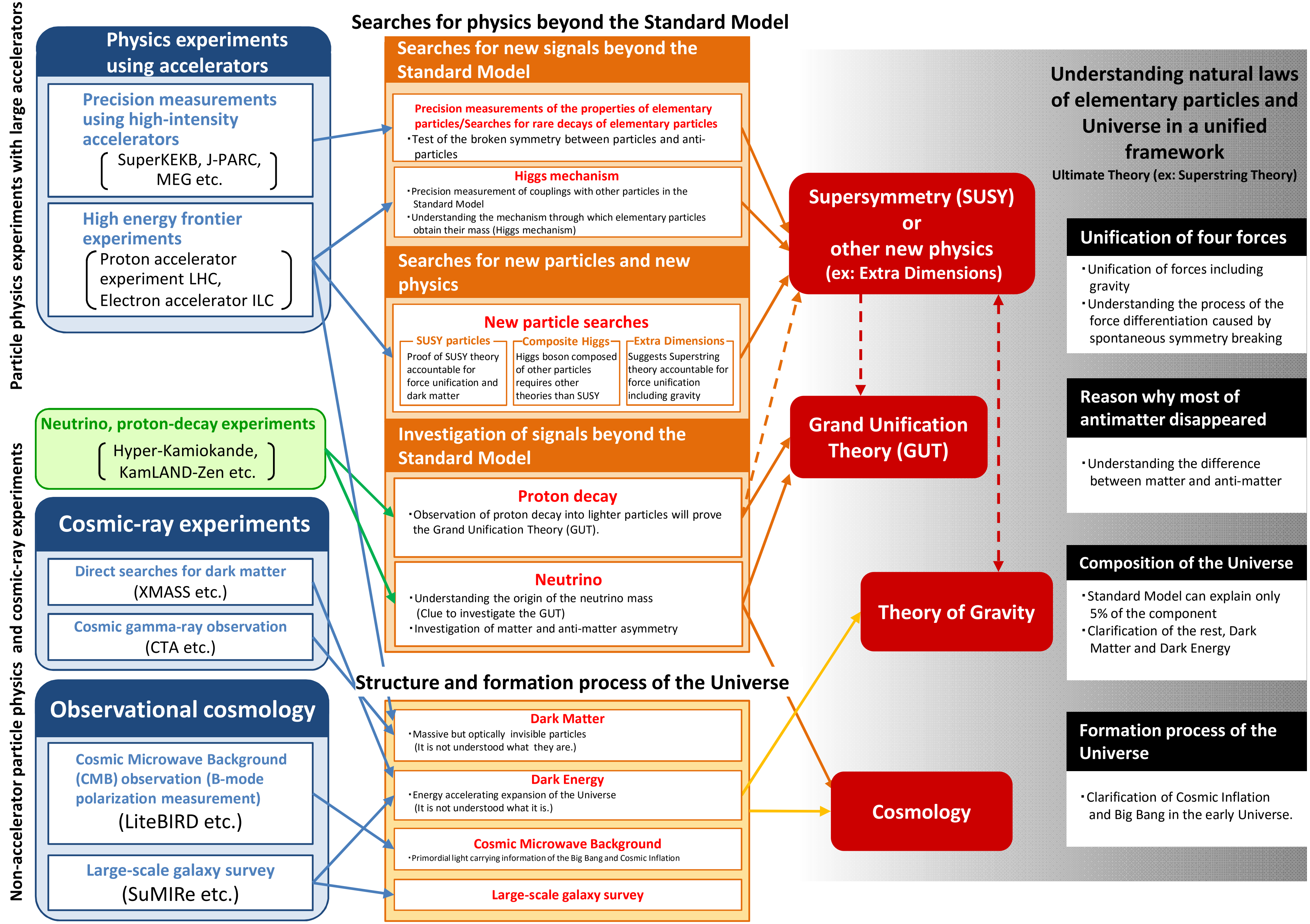
Linear Collider Board
International board that promotes linear collider projects; Founded in 2013 through a reorganization of the ILCSC

Linear Collider Collaboration
International organization that promote multilateral discussion and technology development for linear collider projects

ILC Research and Development
Executes ILC R&D as part of LCC

Edited by MEXT based on information provided at the 1st working group meeting on the organization and management for ILC

Challenges and activities to understand natural laws in a unified framework



Focal Points for the Advisory Panel on the Report Entitled

"Re-calculation Results of Economic Ripple Effects on International Linear Collider (ILC) Project"

1. Premises of the economic ripple effect estimation

(1) Calculate the ILC-specific economic ripple effects arising from ILC as effects-generating sources.

(2) Calculate the economic ripple effects on Japan (industry) with Japan's expected burdens for ILC construction (as assumed in this survey).

(3) The expenditure that accounts for the effects-generating sources of ILC comes from the number posted in TDR in principle. However, part of said expenditure that can be estimated quantitatively with a certain degree of certainty will be targeted for the calculation.

(4) The measurement period for ILC's economic ripple effects (amounts generated) is set as 20 years: a decade each for construction and operation.

(5) With regard to the economic ripple effects from "construction" of ILC, the expenses (investment expenditures) that are not yet posted in TDR but occur as ILC-specific expenses, regardless of the undetermined prerequisites at present, are not included in the effects-generating sources, as follows:

■ Preparatory expenses, common foundation expenses and major research facility construction costs

(6) With regard to the economic ripple effects from "activities" of ILC, the expenditures that are not yet posted in TDR but occur as ILC-specific expenditures, regardless of the undetermined prerequisites at present, are not included in the effects-generating sources, as follows:

■ Expenditures for operating costs of participating/located research institutes and consumption expenditures by ILC-related visitors/conference participants

2. Validity, requirements and limits in applying the CERN business expansion coefficient "3.0"

(1) Calculate the ILC-specific economic ripple effects arising from ILC as effects-generating sources.

○ A system is in place, with which the ILC International Research Institute (tentative name) itself carries out technological development (new/improvement) and transfers technology developed accordingly to supplier companies under contract

○ The ILC International Research Institute places numerous orders to supplier companies under contract for procuring products while transferring technology

○ Many technology-intensive companies are included in the list of supplier companies contracted with the ILC International Research Institute (approximately 10% or more of all contract companies in number, if you refer to CERN)

○ High-value technology transfer annually occurs from the ILC International Research Institute to private companies in 15-20 cases on average over the decade-long construction period (assuming a level equivalent to the performance of CERN's LHC)

(2) It should be noted that the business expansion coefficient "3.0" cannot always be achieved, even if ILC meets the above conditions, because the (necessary and sufficient) evidence and achievement conditions of the coefficient "3.0" through CERN's technology transfer cannot be accurately determined.

3. Summary of ILC's economic ripple effects estimation and interpretation of the multiplier "1.95 ~ 1.96"

(1) ILC's economic ripple effects arising from both "economic ripple effects by construction and activities" and "economic ripple effects by technological development" (ILC-specific effects, which are estimated to occur over 20 years with a decade each for construction and operation) are as follows: The final demand to be generated amounts to 1,216.6 ~ 1,333.8 billion yen and the production to be induced amounts to 2,377.6 ~ 2,610.9 billion yen, equating to a multiplier of 1.95 ~ 1.96 times.

(2) Comparing the multiplier of ILC within the range of 1.95 ~ 1.96 times with other final demand items, it is 1.66 and 1.73 times with respect to "Gross domestic fixed capital formation (private)" and "Gross domestic fixed capital formation (public)," respectively. Accordingly, while the ILC multiplier is numerically larger, given that the production inducement amount of ILC includes secondary indirect effects (the multiplier of 1.95 ~ 1.96 times has a different meaning from the production inducement coefficient in the input-output table) and the sector classification of the input-output table used in this survey is too rough to evaluate correctly, a comparison simply cannot be made.

[Production inducement coefficients by final demand items (54 sectors):
Extended Input-Output Table in 2014]

- Private final consumption expenditure 1.62
- Gross domestic fixed capital formation (private) 1.66
- Gross domestic fixed capital formation (public) 1.73
- Exports 2.06

Chart 1 Economic ripple effects of after-review ILC project (250 GeV ILC) (Summary)

Re-calculation results (minimum scenario) Civil engineering work: 111.0 billion yen Equipment procurement: 173.6 billion yen

	ILC construction	ILC activities	Additional business generated by ILC	Total
Final demand (billion yen)	284.6	411.2	520.8	1,216.6
Induced production (billion yen)	642.2	786.5	948.9	2,377.6
Direct effects	252.7	381.3	391.9	1,025.9
Primary indirect effects	254.7	243.0	377.4	875.1
Secondary indirect effects	134.9	162.1	179.5	476.5
(Of which) Induced gross value added (billion yen)	267.4	405.9	389.5	1,062.8
(Of which) Induced employee income (billion yen)	164.9	215.2	236.0	616.1
Induced number of employees <total number> (1,000 persons)	34.2	49.0	49.4	132.6
Induced number of employees <annual average> (1,000 persons/year)	3.4	2.5		

Re-calculation results (maximum scenario) Civil engineering work: 129.0 billion yen Equipment procurement: 191.9 billion yen

	ILC construction	ILC activities	Additional business generated by ILC	Total
Final demand (billion yen)	320.9	437.2	575.7	1,333.8
Induced production (billion yen)	725.5	836.5	1,048.9	2,610.9
Direct effects	285.6	405.1	433.3	1,124.0
Primary indirect effects	286.5	258.9	417.2	962.6
Secondary indirect effects	153.4	172.5	198.4	524.3
(Of which) Induced gross value added (billion yen)	303.1	430.6	430.5	1,164.3
(Of which) Induced employee income (billion yen)	187.5	229.0	260.8	677.4
Induced number of employees <total number> (1,000 persons)	38.9	52.1	54.6	145.6
Induced number of employees <annual average> (1,000 persons/year)	3.9	2.6		

(3) The multiplier "1.95 ~ 1.96" is the ratio of production inducement to the generation of final demand arising from ILC. Note that **it does not mean a net benefit to the cost put in by constructing and operating ILC**, as occurs with the production inducement coefficient of each sector in the input-output table.

***Reference 1: "Survey analysis on research trends in countries worldwide, including technical/economic ripple effects with respect to the International Linear Collider (ILC) project and technical aspects in the field of elementary particles/nuclear physics"**
(March 2015, Nomura Research Institute)

In the pre-review ILC project (500 GeV ILC), it was assumed that the economic ripple effects of ILC arising from both "economic ripple effects by construction and activities" and "economic ripple effects by technological development" (ILC-specific effects, which are estimated to occur over 20 years with a decade each for construction and operation) are as follows: The final demand to be generated amounts to 2,100 billion yen and the production to be induced amounts to 4,460 billion yen.

In addition, according to the above calculation results, while a certain amount of technical ripple effects arising from the ILC project are expected, judging from past relevant cases, there is not necessarily any prospect of ILC-specific technology being applied to general consumer technology and product development.

Chart 2 Economic ripple effects of the pre-review ILC project (500 GeV ILC) (Summary)

FY2014 Survey — Civil engineering work: 160.0 billion yen — Equipment procurement: 271.5 billion yen

	ILC construction	ILC activities	Additional business generated by ILC	Total
Final demand (billion yen)	431.5	862.5	814.5	2,108.5
Induced production (billion yen)	1,038.9	1,774.7	1,647.0	4,460.6
Direct effects	401.2	817.2	696.6	1,915.0
Primary indirect effects	409.0	579.8	597.8	1,586.6
Secondary indirect effects	228.7	377.7	352.6	959.0
(Of which) Induced gross value added (billion yen)	462.0	943.1	797.5	2,202.6
(Of which) Induced employee income (billion yen)	267.2	472.1	453.5	1,192.8
Induced number of employees <total number> (1,000 persons)	54.7	104.4	95.6	254.7
Induced number of employees <annual average> (1,000 persons/year)	5.5	5.2		

***Reference 2: "Opinions on International Linear Collider Project" (Gist)**
(September 2013, Science Council of Japan)

2 Consideration of each matter for which a request for deliberation was received:

(3) Significance of implementing the ILC project in Japan for its citizens and society

② Ripple effects

Technological ripple effects: ILC-related technological development, including accelerator-related technology, is expected to produce a certain degree of ripple effects in relevant fields. However, it is unlikely that highly specialized ILC-related technology will be immediately applied to general consumer technology or directly to product development.

(omitted)

Discussing ripple effects on either technological development or economic activity is secondary and does not therefore constitute a main argument to justify the ILC project requiring a huge budget.